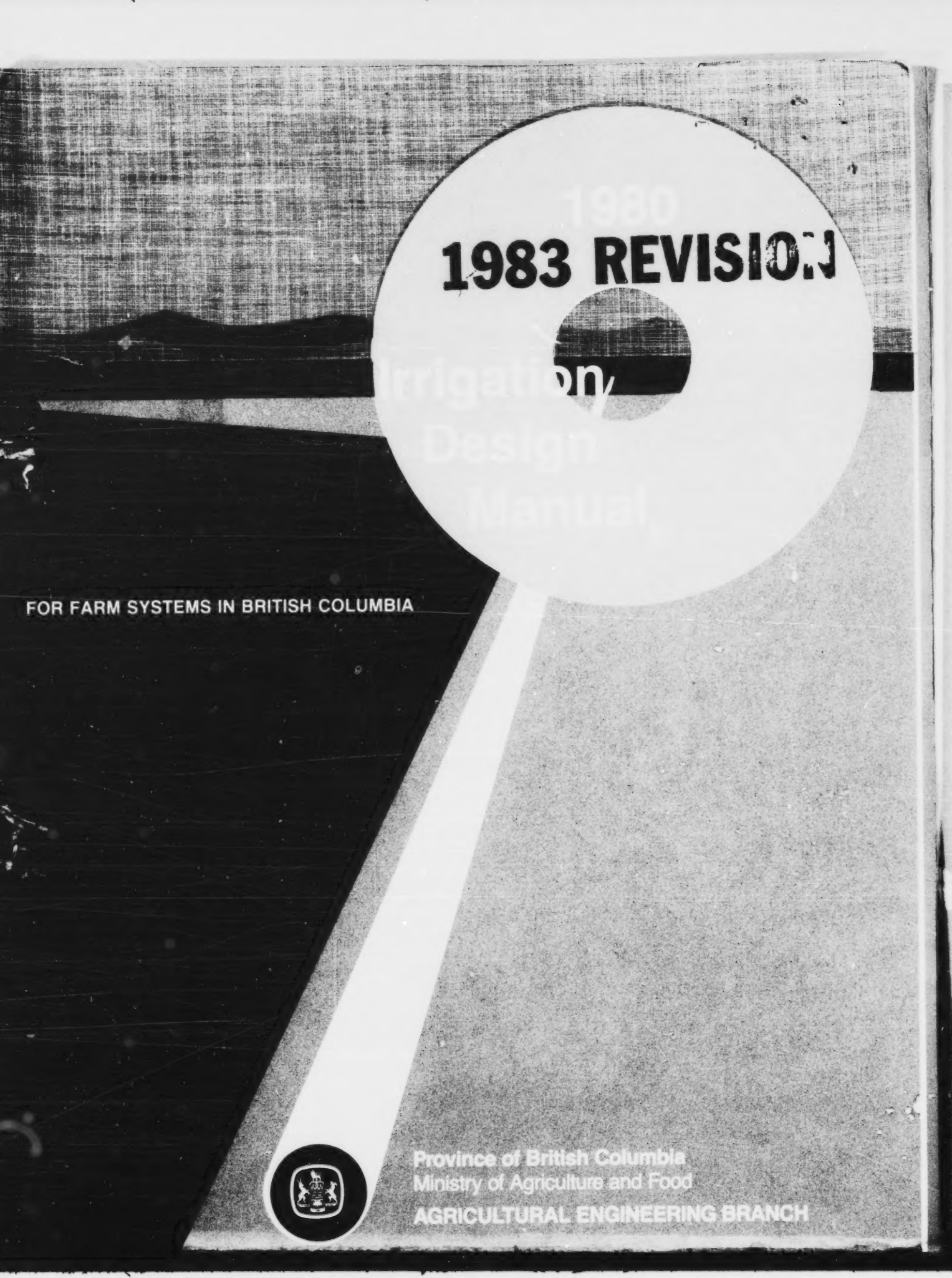
1983 REVISION
FOR FARM SYSTEMS IN BRITISH COLUMBIA
Province of British Columbia
Ministry of Agriculture and Food
AGRICULTURAL ENGINEERING BRANCH

1980
IRRIGATION DESIGN MANUAL FOR FARM SYSTEMS IN BRITISH COLUMBIA

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1983 REVISION

Province of British Columbia

Ministry of Agriculture and Food

Canadian Cataloguing in Publication Data

Main entry under title:
1980 irrigation design manual for farm systems
in British Columbia

Bibliography: p.
ISBN 0-7719-9083-9

1. Irrigation - British Columbia. 2. Irrigation engineering - British Columbia. I. British Columbia Irrigation Committee. II. British Columbia. Agricultural Engineering Branch. III. Title: Irrigation design manual for farm systems in British Columbia.

S616.C3N56 1983 631.7'09711 C82-092326-5

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IRRIGATION DESIGN MANUAL

FOR FARM SYSTEMS IN BRITISH COLUMBIA

INTRODUCTION

This Irrigation Design Manual provides information for designing systems in British Columbia. To design an irrigation system, the designer must compile information on soil characteristics, crops to be grown, peak evapotranspiration rate, type of irrigation system, and water supply. Much of this information is contained in this publication; however flood, furrow and sub-surface irrigation have not been covered. Actual field trials should be conducted where more specific design information is required. Some of the design information has been compiled from various publications listed in the Bibliography. New sections on Stationary Gun, Travelling Gun, Center-Pivot and Trickle Irrigation have been included in the 1980 revision.

Soil, Water and Crop Information

The soil, crop and climatic characteristics determine the requirements that an irrigation system must fulfill. The effective rooting depth of the mature crop, the available water storage capacity of the soil down to the effective rooting depth, the availability of the water to the crop and the infiltration rate of the soil all affect the design of an irrigation system.

Crop Water Use

The values presented on peak evapotranspiration were calculated from evaporation measurements under the guidance of Dr. J.C. Wilcox under the ARDA Canada Land Inventory (See Bibliography No. 2). These rates have been tied directly to maximum soil water deficits for various regions throughout British Columbia.

The table on Average Seasonal Potential Evapotranspiration to Estimate the Crop Land Required for a Municipal Effluent Irrigation System has been removed from previous Design Manuals and new Average Seasonal Irrigation Requirement data is now incorporated in the Pollution Control Guidelines for Municipal Effluent Application to Land.

Sprinkler Selection

Optimum sprinkler spacing combinations determined by the Agricultural Engineering Branch, British Columbia Ministry of Agriculture and Food, provide a rapid technique for selecting sprinklers based on application efficiency, operating pressure and required application rate. The selections are based on numerous water distribution patterns generated from field tests. All the sprinkler spacing combinations listed in the tables show a relatively high application efficiency.

Stationary Gun Sprinklers

A new section has been added that provides data on stationary gun system design. Even though overlapped application rates are important for the overall design, the actual instantaneous application rates will often determine the sprinkler selection due to soil limitations. The data have been generated from numerous field tests run by the Agricultural Engineering Branch, British Columbia Ministry of Agriculture and Food.

Travelling Gun Sprinklers

Tables have been included in this new section that show the depth of water applied for various sizes, lane spacings and travel speeds. Ranges of application rates are given and due to the high rates caution should be exercised in the design of these systems.

Center-Pivot Irrigation

Formulas, tables and graphs have been generated in this new section that should assist in the basic design of a Center-Pivot irrigation system. The soil capabilities and system capacity are again stressed.

Trickle Irrigation

The application of water to a tree or plant in an amount sufficient to replenish that water used during the past day is the basic principle behind tickle irrigation. In this new section, both point source emitters and spray emitters are discussed and basic design data are provided. The importance of component selection, filtration and chlorination is outlined and guidance is given. Charts, tables and formulas pertaining only to trickle irrigation design are included in this section.

General Design Information

The latter portion of the Manual presents friction losses and pressure ratings for various types and sizes of pipes, comparative pipe flow capacity, pressure losses in pipe fittings, pump and power selections and general design information to consider when designing and installing irrigation systems.

Examples are given throughout the Manual showing the use of the various tables. Sample irrigation plans showing all the pertinent design information and details for a particular crop, location and system layout have been included in the back of the Manual.

Unless otherwise specified all volumes are in U.S. gallons.

NOTE: A glossary of terms is given at the back of this Manual. The first time a word or term appears in the text that is defined in the Glossary, it is capitalized.

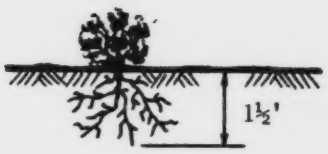
PART I – EFFECTIVE ROOTING DEPTHS OF MATURE CROPS FOR IRRIGATION

The EFFECTIVE ROOTING DEPTH of a mature crop is that depth of soil from which a crop removes significant amounts of water. The normal effective rooting depths for crops grown in deep, uniformly porous, friable and fertile soils are given in Table 1. These depths must be modified for soils which do not permit normal root development. Compaction of the surface soil, excessively coarse subsoil, impervious subsoil, poor soil drainage, high water tables, chemical and fertility problems may inhibit normal root development and reduce the effective rooting depth for irrigation.

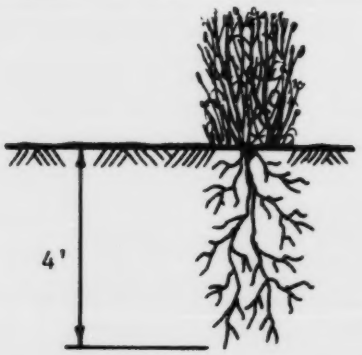
NOTE: The irrigation design must be based on mature crop requirements. More frequent irrigation will be required until full rooting depth is reached with plant maturity.

TABLE 1 EFFECTIVE ROOTING DEPTH OF MATURE CROPS FOR IRRIGATION SYSTEM DESIGN

Shallow	Medium Shallow	Medium Deep	Deep
1½ feet	2 feet	3 feet	4 feet
Cabbages	Beans	Brussels Sprouts	Alfalfa
Cauliflowers	Beets	Cereals	Asparagus
Clover (ladino)	Broccoli	Clover (red)	Cane fruits
Cucumbers	Carrots	Corn (sweet)	Corn (field)
Lettuce	Celery	Eggplant	Grapes
Onions	Peas	Peppers	Sugar Beets
Pasture species	Potatoes	Squash	Tree Fruits
Radishes	Spinach		
Turnips	Strawberries		
	Tomatoes		



Shallow rooted crop (lettuce)



Deep rooted crop (alfalfa)

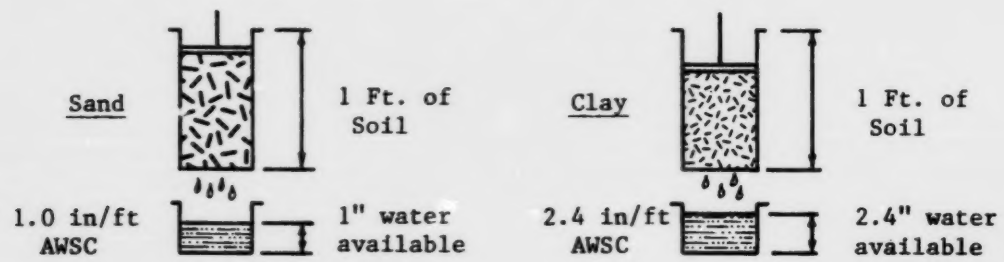
PART II – AVAILABLE WATER STORAGE CAPACITY OF SOILS

The capacity of a soil to store water depends upon the particle size composition of the soil (texture) and the soil particle arrangement (structure). To obtain an estimate of the water holding capacity of a soil it is necessary to determine soil textures within the effective rooting depth of the crop to be irrigated. Samples for assessment may be submitted to the Soils Branch, British Columbia Ministry of Agriculture and Food, 1873 Spall Road, Kelowna, British Columbia V1Y 4R2, or 17720 - 57th Avenue, Surrey, British Columbia V3S 4P9. Alternatively, soil survey maps and reports, where appropriate, may be used to calculate the texture of the soil horizons and Table 2 can be used to calculate the AVAILABLE WATER STORAGE CAPACITY (AWSC). To obtain the best estimates, however, soil samples for laboratory analyses are required. The total AWSC of the effective rooting zone is obtained by adding the AWSC of the various textural layers. The AWSC must be modified as described in Part III to determine the maximum soil water deficit (useable storage capacity).

The procedure for taking soil samples for irrigation system design is outlined in Appendix I.

TABLE 2 A GUIDE TO AVAILABLE WATER STORAGE CAPACITIES (AWSC) OF SOILS

Textural Class	Available Water Storage Capacity (AWSC) in Inches of Water per Foot of Soil
Sand	1.0
Loamy Sand	1.2
Sandy Loam	1.5
Fine Sandy Loam	1.7
Loam	2.1
Silt Loam	2.5
Clay Loam	2.4
Clay	2.4
Organic Soils (muck)	3.0



PART III – MAXIMUM SOIL WATER DEFICIT

The MAXIMUM SOIL WATER DEFICIT is the maximum amount of water in inches allowed to be removed from the soil before irrigation is required. It is calculated by multiplying the AWSC of the soil to the effective rooting depth by a suitable AVAILABILITY COEFFICIENT. Availability coefficients for various crops are listed in Table 3.

TABLE 3 AVAILABILITY COEFFICIENTS

Crop	Maximum Percent (%)
Peas	35
Potatoes	35
*Tree Fruits	40
Grapes	40
Tomatoes	40
Other crops until additional data becomes available	50

* Changed from previous Manual

PART IV – MAXIMUM DESIGN APPLICATION RATES

The rate of application of water should be limited to how rapidly water can enter the soil. There should be no puddling of water under sprinklers if a system is properly designed. The values given in Table 4 are estimated maximum APPLICATION RATES for various soil textures under normal irrigation practices. Field tests under actual sprinkler conditions should be conducted for more accurate application rates.

TABLE 4 MAXIMUM DESIGN APPLICATION RATES

Textural Class	Application Rate (in/hr)	
	Grass Sod	Cultivated
Sand	0.75	0.40
Loamy sand	0.65	0.35
Sandy loam	0.45	0.25
Fine sandy loam	0.40	0.25
Loam	0.35	0.20
Silt loam	0.35	0.20
Clay loam	0.30	0.15
Clay	0.25	0.10
Organic soils (muck)	0.50	0.50

Sand

High infiltration rate

Clay

Low infiltration rate

PART V – PEAK EVAPOTRANSPIRATION

EVAPOTRANSPIRATION (ET) is a measure of the rate at which water is transpired by plants plus that evaporated from the soil surface. Values presented in Table 5 represent the best estimates of the highest average ET during an IRRIGATION INTERVAL (Summerland Irrigation Circular No. 10).

The peak ET averaged over the irrigation interval decreases as the interval increases. The maximum soil water deficit divided by peak ET equals the irrigation interval in days. Since the irrigation interval is related to the AWSC of the soil, peak ET decreases with an increase in maximum soil water deficit. This Manual provides a new approach to irrigation by giving peak ET values for maximum soil water deficits of 1 to 5 inches of water.

TABLE 5 PEAK EVAPOTRANSPIRATION (ET) IN INCHES PER DAY FOR MAXIMUM SOIL WATER DEFICITS

Location	Maximum Soil Water Deficits (Inches of Water)				
	1"	2"	3"	4"	5"
Abbotsford	.18	.16	.15	.14	.14
Agassiz	.18	.16	.15	.14	.14
Alexis Creek	.18	.16	.15	.14	.14
Armstrong	.26	.23	.21	.20	.19
Ashcroft	.36	.32	.30	.29	.28
Aspen Grove	.27	.23	.21	.20	.20
Barriere	.24	.21	.20	.19	.18
Baynes Lake	.28	.26	.25	.24	.23
Campbell River	.28	.22	.20	.18	.17
Canal Flat	.30	.28	.26	.25	.25
Castlegar	.36	.33	.31	.30	.29
Cawston	.38	.34	.32	.31	.30
Chase	.24	.22	.21	.20	.20
Cherryville	.23	.22	.21	.20	.20
Chilliwack	.21	.19	.17	.16	.16
Clinton	.26	.24	.23	.22	.22
Cloverdale	.18	.16	.14	.13	.13
Comox	.28	.22	.20	.18	.16
Creston	.20	.19	.18	.18	.17
Donald	.16	.14	.14	.13	.13
Douglas Lake	.23	.21	.21	.20	.20
Duncan	.20	.17	.16	.15	.15

TABLE 5 (cont'd) PEAK EVAPOTRANSPIRATION (ET) IN INCHES PER DAY FOR MAXIMUM SOIL WATER DEFICITS

Location	Maximum Soil Water Deficits (Inches of Water)				
	1"	2"	3"	4"	5"
Ellison	.27	.24	.23	.21	.21
Fort Fraser	.22	.20	.19	.18	.18
Fort Steele	.26	.23	.22	.21	.20
Golden	.17	.15	.15	.14	.14
Grand Forks	.21	.19	.19	.18	.18
Grandview Flats	.29	.27	.25	.24	.24
Grasmere	.26	.23	.22	.21	.20
Grindrod	.19	.16	.14	.14	.13
Hazelton	.22	.19	.19	.19	.19
Hixon	.18	.16	.16	.15	.15
Hope	.28	.25	.22	.21	.20
Invermere	.27	.25	.23	.22	.21
Joe Rich	.21	.18	.16	.15	.15
Jura	.28	.24	.22	.21	.20
*Kamloops	.33	.30	.28	.27	.26
Kelowna	.28	.25	.24	.23	.22
Keremeos	.31	.30	.29	.28	.28
Kersley	.24	.23	.22	.22	.22
Kettle Valley	.29	.28	.27	.26	.26
Kimberley	.34	.32	.30	.28	.27
Ladner	.16	.14	.13	.13	.12
Langley	.17	.14	.14	.13	.12
*Lillooet	.33	.30	.28	.27	.26
Lister	.23	.21	.21	.20	.20
Lumby	.27	.24	.23	.22	.21
Lytton	.36	.32	.30	.28	.28
Malakwa	.23	.20	.19	.19	.18
Merritt	.30	.28	.26	.25	.25
Nanaimo	.26	.21	.19	.17	.16
Natal	.21	.19	.18	.17	.17
Notch Hill	.24	.21	.20	.19	.18

TABLE 5 (cont'd) PEAK EVAPOTRANSPIRATION (ET) IN INCHES PER DAY FOR MAXIMUM SOIL WATER DEFICITS

Location	Maximum Soil Water Deficits (Inches of Water)				
	1"	2"	3"	4"	5"
Oliver	.29	.26	.24	.23	.23
One Hundred Mile House	.26	.24	.23	.22	.22
Osoyoos	.33	.30	.28	.27	.26
Oyster River	.14	.13	.12	.11	.11
Parksville	.21	.17	.16	.15	.14
Pitt Meadows	.16	.14	.13	.12	.12
Port Alberni	.28	.23	.20	.19	.18
Prince George	.18	.16	.15	.15	.14
Princeton	.28	.26	.25	.23	.23
Quesnel	.29	.27	.26	.25	.25
Radium	.23	.21	.20	.19	.19
Riske Creek	.31	.29	.28	.27	.27
*Saanichton	.19	.17	.16	.15	.15
Salmon Arm	.19	.17	.17	.16	.16
Smithers	.18	.16	.15	.14	.14
Spillimacheen	.23	.20	.19	.18	.18
Sumas	.20	.18	.17	.16	.15
Summerland	.30	.28	.26	.24	.24
Terrace	.32	.31	.30	.29	.28
Vancouver	.24	.20	.18	.17	.16
Vanderhoof	.21	.20	.20	.19	.19
Vavenby	.19	.17	.16	.15	.14
Vernon	.26	.23	.22	.21	.21
Walhachin	.31	.30	.29	.28	.27
Westwold	.30	.28	.27	.26	.25
Williams Lake	.30	.29	.28	.27	.26

* Values adjusted to actual field experience

PART VI – ESTIMATED ANNUAL IRRIGATION REQUIREMENTS

The maximum ANNUAL IRRIGATION REQUIREMENTS shown in Table 6 are the best estimates for maximum demand crops such as alfalfa and tree fruits for the locations shown. For crops which are not irrigated for the full season, these estimates will be proportionately less. Application efficiencies have been incorporated in the values shown in the tables.

TABLE 6 ESTIMATED ANNUAL IRRIGATION REQUIREMENTS (INCHES) FOR MAXIMUM SOIL WATER DEFICITS

Location	Maximum Soil Water Deficits (Inches of Water)				
	1"	2"	3"	4"	5"
Abbotsford	25	17	12	8	5
Agassiz	18	9	6	4	2
Alexis Creek	26	19	15	12	9
Armstrong	29	22	17	14	11
Ashcroft	53	42	35	31	27
Aspen Grove	31	23	18	15	12
Barriere	30	22	18	14	12
Baynes Lake	38	28	23	19	16
Campbell River	25	17	14	11	9
Canal Flat	33	25	20	17	14
Castlegar	46	35	29	25	21
Cawston	53	42	35	31	27
Chase	36	27	21	18	14
Cherryville	34	24	19	16	14
Chilliwack	19	9	7	5	3
Clinton	37	28	24	20	17
Cloverdale	21	14	10	7	4
Comox	27	20	16	13	11
Creston	33	26	22	18	16
Donald	19	13	9	6	3
Douglas Lake	34	26	22	19	16
Duncan	21	15	12	10	8

TABLE 6 (cont'd) ESTIMATED ANNUAL IRRIGATION REQUIREMENTS (INCHES) FOR MAXIMUM SOIL WATER DEFICITS

Location	Maximum Soil Water Deficits (Inches of Water)				
	1"	2"	3"	4"	5"
Ellison	37	28	23	20	17
Fort Fraser	21	15	11	8	5
Fort Steele	26	18	14	11	8
Golden	27	19	15	13	11
Grand Forks	26	19	15	12	10
Grandview Flats	40	30	25	22	19
Grasmere	31	23	18	15	12
Grindrod	20	14	10	7	4
Hazelton	10	6	3	1	0
Hixon	21	13	9	5	3
Hope	28	17	13	10	7
Invermere	39	29	24	19	16
Joe Rich	28	20	16	13	10
Jura	31	21	16	13	10
Kamloops	45	36	32	28	26
Kelowna	41	31	26	23	20
Keremeos	45	36	32	28	26
Kersley	23	17	13	10	8
Kettle Valley	41	31	25	21	18
Kimberley	40	30	24	20	17
Ladner	21	15	11	9	6
Langley	20	12	9	7	5
Lillooet	41	32	27	23	20
Lister	34	26	22	18	15
Lumby	34	26	21	18	15
Lytton	51	40	35	31	27
Malakwa	22	16	12	9	7
Merritt	44	34	29	25	21
Nanaimo	25	18	14	11	8
Natal	27	19	14	11	8
Notch Hill	32	24	20	16	14

TABLE 6 (cont'd) ESTIMATED ANNUAL IRRIGATION REQUIREMENTS (INCHES) FOR MAXIMUM SOIL WATER DEFICITS

Location	Maximum Soil Water Deficits (Inches of Water)				
	1"	2"	3"	4"	5"
Oliver	49	38	34	30	27
One Hundred Mile House	37	28	24	20	17
Osoyoos	50	40	35	31	28
Oyster River	18	12	9	6	4
Parksville	25	18	14	12	10
Pitt Meadows	18	12	8	4	2
Port Alberni	27	20	16	13	10
Prince George	24	18	14	11	9
Princeton	41	29	25	22	20
Quesnel	22	16	13	10	8
Radium	29	21	17	13	10
Riske Creek	35	26	22	18	15
Saanichton	25	17	14	12	10
Salmon Arm	29	22	18	15	12
Smithers	22	16	12	9	7
Spillimacheen	33	24	19	15	12
Sumas	22	14	9	6	4
Summerland	42	32	27	24	21
Terrace	22	16	12	10	8
Vancouver	25	19	15	12	10
Vanderhoof	23	16	11	8	5
Vavenby	29	22	18	15	12
Vernon	34	26	22	19	16
Walhachin	43	33	28	24	20
Westwold	43	33	28	25	22
Williams Lake	31	23	18	15	12

PART VII – IRRIGATION DISTRICT WATER ALLOTMENTS

NOTE: 1) Allotments may vary within a District because of different soil types. Contact the respective District to ensure you are designing to the WATER ALLOTMENT for the location with which you are concerned. When requesting this information, provide the irrigator's name, the legal description of the area to be irrigated, the names of the road or roads on which the property is located and the acreage.

2) Some Districts list allotments in Imperial gallons.

TABLE 7 WATER ALLOTMENTS FOR VARIOUS DISTRICTS

District	Phone Number	Water Allotment	
		gpm (U.S.) Per Acre	gpm (Imp.) Per Acre
Black Mountain	765-5169	5 to 7	
Black Sage	498-2929	8	
Cawston	499-5795	6.6 and 7.7	
Chase	679-3589	6	
East Creston	428-2612	4.5	
Ellison	765-5539	5	
Erickson	428-9677		2.5
Fairview Heights	499-2460	6.6 and 7.6	
Glenmore	763-6506	4 and 6	
Kaleden	497-5454, 497-5407	6.25	
Keremeos	499-5651	6 to 8	
Lakeview	769-4322		5.6
Naramata	496-5420	5	
North Canyon	428-2765	3	
Okanagan Falls	497-5509, 497-5463	6	
Osoyoos	495-6024 495-6483	8	
Oyama	548-3831, 548-3378, 548-3536	6	
Peachland	767-2393		6

TABLE VII (Cont'd) WATER ALLOTMENTS FOR VARIOUS DISTRICTS

District	Phone Number	Water Allotment	
		gpm (U.S.) Per Acre	gpm (Imp.) Per Acre
Penticton	492-3043	5, 6 and 7	
South East Kelowna	860-3488	5, 6 and 6.5	
South Okanagan Lands	498-3666	7.75 to 8.25	
St. Mary's Prairie		4.5	
Summerland	494-6451		6
Vernon	542-2329	5	
Westbank	768-5154	5 to 6.5	
Winfield-Okanagan Centre	766-2648	5 to 6.5	
Woods Lake	548-3831, 548-3378, 548-3536	6.25	
Wynndel	866-5392	4.45	

PART VIII – STATIONARY SPRINKLERS

8.1 Sprinkler and Spacing Selection

The proper choice of sprinkler-spacing combination to apply water in a uniform pattern is of great importance in the design of an efficient irrigation system. Every nozzle combination has a specific operating pressure range. Too much pressure will disperse water into a fine spray resulting in increased evaporation losses and poor distribution. Too little pressure may cause puddling, runoff, poor distribution and crop damage. The sprinkler spacing combinations presented in Tables 8.2a - 8.2g have been selected from distribution tests carried out by the Agricultural Engineering Branch, B.C. Ministry of Agriculture and Food, utilizing a combination of statistical data provided by field tests and field experience.

Although only rectangular spacings are shown it should be noted that triangular spacings may increase the APPLICATION EFFICIENCY in tree plantings.

8.2 Types of Stationary Sprinkler Systems

8.2.1 Hand-Move System

A HAND-MOVE SYSTEM usually consists of a system of piping which is moved by uncoupling and moving the pipes manually.

8.2.2 Wheel-Move System

A WHEEL-MOVE SYSTEM consists of wheels mounted on the pipeline so that the LATERAL acts as an axle. A powered mover on the line rolls the lateral ahead when the system is shut down. The pipeline remains stationary when the irrigation system is in operation and can only be moved after the line has been drained.

8.2.3 Solid-Set System

A SOLID-SET SYSTEM is usually a permanent installation consisting of above or below ground piping with permanent sprinklers situated throughout the entire area at the proper spacing.

8.3 Formulas Used

Flow per sprinkler (gpm) =

$$\frac{\text{Sprinkler Spacing (ft)} \times \text{Lateral Spacing (ft)} \times \text{Application Rate (in/hr)}}{96.3}$$

Maximum Square Spacing = Wetted diameter x 0.60 (Wind up to 4 mph)
Wetted diameter x 0.50 (Wind 4 to 8 mph)
Wetted diameter x 0.40 (Wind over 8 mph)

Refer to manufacturers' charts for wetted diameters.

$$\text{Irrigation Interval (Days)} = \frac{\text{Maximum Soil Water Deficit (in)}}{\text{Peak ET Rate (in/day)}}$$

Note: Total allowable friction loss along any one lateral shall not exceed 20% of the sprinkler operating pressure.

8.4 Sample Design Problem

A farmer near Merritt intends to grow alfalfa on a sandy loam soil. The design of his irrigation system needs to meet maximum crop water demands. For a stationary sprinkler system what nozzle sizes, spacing, pressure, flow per sprinkler (gpm) and interval will be required?

From: Table 1 - Alfalfa crop - effective rooting depth is 4 feet.
However, soil samples indicate that rooting depth is restricted to 3 feet. In this case, the soil is limiting, therefore the effective rooting depth is only 3 feet.

Table 2 - Sandy loam soil - available water storage capacity is 1.5 in/ft.
For an effective rooting depth of 3 ft. the total AWSC is 3 ft. x 1.5 in/ft =4.5 inches.
This type of information is usually derived from soil sample analysis.

Table 3 - Availability coefficient - for alfalfa it is 50%. The amount of water available to the crop is 50% x 4.5 inches = 2.25 inches (maximum soil water deficit).

Table 4 - Maximum application rate for a sandy loam soil with a sod crop is 0.45 inches/hour.

Table 5 - Evapotranspiration rate in Merritt for a 2.25 in. maximum soil deficit is 0.28 in/day.

$$\text{Irrigation Interval} = \frac{\text{maximum soil water deficit (in)}}{\text{Peak ET (in/day)}}$$

$$= \frac{2.25 \text{ in}}{0.28 \text{ in/day}} = 8 \text{ days}$$

From the Sprinkler Selection Table - for this example a 40 ft. x 60 ft. spacing is selected.

Application Efficiency - for Merritt, hot climate, an average application efficiency is 72% (shown in the sprinkler selection Table 8.2e).

$$\text{Gross Water required} = \frac{\text{maximum soil water deficit (in)}}{\text{Application Efficiency (\%)}}$$

$$= \frac{2.25 \text{ in.}}{0.72} = 3.13 \text{ in.}$$

Select an 11½ hour set time. (Allow ½ hour for moving).

$$\text{Application rate} = \frac{\text{Gross water required (in)}}{\text{set time (hrs)}}$$

$$= \frac{3.13 \text{ in}}{11\frac{1}{2} \text{ hr}}$$

= 0.27 in/hr (This is less than the maximum allowed by the soil so it is acceptable).

From the 40 ft. x 60 ft. Table 8.2e the following information can be extracted:

Spacing	- 40' x 60'
Application Rate	- 0.27 in/hr.
Sprinkler Nozzle Size	- 5/32" x 3/32"
Pressure at Nozzle	- 49 psi
Flow per Sprinkler	- 6.73 gpm
Wind Range	- 2-6 mph
Application Efficiency	- 72%

The following design criteria can now be used to determine the layout of the irrigation system:

The sprinkler system consists of 5/32" x 3/32" nozzles operating at 49 psi with a flow of 6.73 gpm. On a 40' x 60' spacing and

an 11½ hour set time the gross application is 3.13 inches. The net amount applied to the crop at an application efficiency of 72% is 2.25 inches, which is enough to last for 8 days at an ET rate of 0.28 in/day. If the irrigator has a water allotment of 5 gpm/acre on a 100 acre parcel, a total of 74 of these sprinklers can be operated at any one time.

8.5 Nozzle Sizes and Pressures Recommended with Flow Control Valves

In areas where an irrigation system receives water from an irrigation district, the system must be designed within a stated water allotment. To ensure that the water allotment is not exceeded, the installation of a FLOW CONTROL VALVE may be required at each sprinkler head. In order to ensure that the sprinkler will still operate properly, the flow control valve must be sized according to nozzle size and pressure. The following Table 8.1 is a guide to help in the selection of a proper flow control valve.

TABLE 8.1 NOZZLE SIZES AND PRESSURES RECOMMENDED WITH FLOW CONTROL VALVES OF STATED SIZES

Flow Control Valve (gpm)	Nozzle Size (in)	Nozzle Pressure (psi)	Minimum Line Pressure Required (psi)
1.5	3/32	35	45
2.0	7/64	34	44
2.5	1/8	31	41
3.0	9/64	28	40
	or 1/8	44	54
3.5	9/64	38	53
4.0	9/64	49	64
5.0	5/32	50	65
	or 1/8 x 3/32	50	65
6.0	11/64	50	65
	or 5/32 x 3/32	39	44
	or 9/64 x 3/32	53	68
7.0	3/16	48	63
	or 11/64 x 3/32	40	55

TABLE 8.2a SPRINKLER SELECTION FOR 30' x 30' SPACING

Application Rate (in/hr)	Sprinkler Nozzle Size (in)	Pressure at Nozzle (psi)	Flow per Sprinkler (gpm)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency	
						Cool Climate (%)	Hot Climate (%)
0.07	1/16	34	0.66	89	2 & 5	78	76
0.08	1/16	43	0.75	89	0 & 2	78	76
0.10	5/64	30	0.95	84	5 & 8	75	73
0.12	5/64	40	1.12	80	2 & 6	78	76
0.15	3/32	30	1.40	90	0 & 3	74	72
0.16	3/32	35	1.55	87	2 & 7	74	72
0.17	3/32	40	1.73	87	2 & 7	80	78
0.20	7/64	30	1.89	84	1 & 6	77	75
0.22	7/64	35	2.05	84	2 & 5	74	72
0.24	7/64	41	2.23	84	2 & 5	77	75
0.26	1/8	30	2.44	80	0 & 3	74	72
0.31	1/8	41	2.90	87	0 & 3	74	72
0.33	9/64	30	3.10	88	0 & 3	80	78
0.39	9/64	41	3.67	80	2 & 4	77	75
0.41	9/64	45	3.84	88	1 & 3	75	73
0.43	9/64	49	4.00	90	2 & 7	77	75
0.50	5/32	44	4.68	89	2 & 7	80	78

TABLE 8.2b SPRINKLER SELECTION FOR 30' x 40' SPACING

Application Rate (in/hr)	Sprinkler Nozzle Size (in)	Pressure at Nozzle (psi)	Flow per Sprinkler (gpm)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency	
						Cool Climate (%)	Hot Climate (%)
0.13	3/32	40	1.62	81	2 & 7	75	73
0.15	7/64	30	1.89	81	1 & 5	74	72
0.20	1/8	31	2.50	83	2 & 5	74	72
0.23	1/8	40	2.87	87	0 & 3	74	72
0.27	9/64	34	3.35	87	1 & 2	74	72
0.29	9/64	40	3.63	84	2 & 5	75	73
0.31	9/64	46	3.88	88	1 & 3	75	73
0.32	9/64	49	4.00	94	2 & 7	76	74
0.33	5/32	34	4.10	85	1 & 3	75	73
0.36	5/32	41	4.50	87	2 & 7	75	73
0.38	5/32	45	4.72	85	2 & 4	78	76
0.40	5/32	50	5.00	87	0 & 7	80	78
0.43	11/64	40	5.37	82	2 & 5	78	76
0.44	9/64x3/32	44	5.45	90	1 & 3	78	76
0.48	11/64	50	6.01	93	1 & 2	80	78
0.49	5/32x3/32	40	6.11	92	5 & 10	80	78

TABLE 8.2c SPRINKLER SELECTION FOR 30' x 60' SPACING

Application Rate (in/hr)	Sprinkler Nozzle Size (in)	Pressure at Nozzle (psi)	Flow per Sprinkler (gpm)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency	
						Cool Climate (%)	Hot Climate (%)
0.20	9/64	43	3.76	85	3 & 6	72	70
0.22	9/64	52	4.13	86	2 & 7	72	70
0.24	5/32	41	4.50	80	2 & 7	72	70
0.25	5/32	44	4.68	89	2 & 7	76	74
0.30	11/64	44	5.64	88	4 & 6	74	72
0.32	11/64	50	6.01	83	0 & 6	74	72
0.33	5/32x3/32	41	6.18	78	5 &10	74	72
0.35	3/16	41	6.49	89	1 & 2	76	74
0.36	3/16	44	6.73	82	0 & 2	74	72
0.38	11/64x3/32	41	7.11	82	5 &10	78	76
0.40	11/64x3/32	45	7.46	88	2 & 3	74	72
0.43	3/16x3/32	40	8.07	86	3 & 6	77	75
0.46	3/16x3/32	45	8.57	88	2 & 4	77	75
0.48	3/16x3/32	50	9.04	92	0 & 1	76	74
0.51	3/16x1/8	40	9.54	91	1 & 2	80	78

TABLE 8.2d SPRINKLER SELECTION FOR 40' x 40' SPACING

Application Rate (in/hr)	Sprinkler Nozzle Size (in)	Pressure at Nozzle (psi)	Flow per Sprinkler (gpm)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency	
						Cool Climate (%)	Hot Climate (%)
0.18	1/8	43	2.98	86	1 & 3	76	74
0.23	9/64	45	3.84	88	1 & 3	74	72
0.25	5/32	35	4.16	85	1 & 3	75	73
0.27	5/32	41	4.50	86	2 & 7	74	72
0.28	5/32	44	4.68	86	2 & 7	75	73
0.30	5/32	50	4.98	93	3 & 7	74	72
0.32	11/64	40	5.37	85	2 & 5	75	73
0.34	5/32x3/32	35	5.70	86	1 & 2	77	75
0.36	11/64	50	6.01	90	1 & 2	80	78
0.37	5/32x3/32	40	6.11	89	5 &10	79	77
0.39	5/32x3/32	45	6.48	90	5 & 7	80	78
0.41	3/16	45	6.81	88	0 & 2	80	78
0.45	11/64x3/32	45	7.46	89	2 & 3	80	78

TABLE 8.2e SPRINKLER SELECTION FOR 40' x 60' SPACING

Application Rate (in/hr)	Sprinkler Nozzle Size (in)	Pressure at Nozzle (psi)	Flow per Sprinkler (gpm)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency	
						Cool Climate (%)	Hot Climate (%)
0.13	1/8	51	3.25	86	1 - 3	75	73
0.14	9/64	37	3.50	85	1 - 2	74	72
0.15	9/64	43	3.75	86	2 - 5	74	72
0.16	9/64	48	3.95	83	2 - 7	74	72
0.17	5/32	37	4.30	80	0 - 1	74	72
0.18	5/32	41	4.50	86	2 - 7	74	72
0.19	5/32	46	4.76	87	5 - 7	74	72
0.21	11/64	38	5.23	86	2 - 5	74	72
0.22	11/64	42	5.51	86	4 - 6	74	72
0.23	11/64	45	5.70	86	3 - 4	75	73
0.24	5/32x3/32	38	6.01	82	3 - 6	74	72
0.25	5/32x3/32	42	6.25	77	5 -10	74	72
0.26	5/32x3/32	45	6.48	79	5 - 7	74	72
0.27	5/32x3/32	48	6.73	82	2 - 6	74	72
0.28	11/64x3/32	40	7.03	82	3 - 4	74	72
0.29	11/64x3/32	42	7.25	83	2 - 3	74	72
0.30	11/64x3/32	45	7.46	85	4 - 7	74	72
0.31	11/64x3/32	47	7.70	84	3 - 6	77	75
0.32	3/16x3/32	40	8.00	84	3 - 6	78	76
0.34	3/16x3/32	44	8.50	83	3 - 7	74	72
0.36	3/16x3/32	49	9.00	84	0 - 1	74	72
0.38	3/16x1/8	40	9.48	84	1 - 2	74	72
0.40	3/16x1/8	44	10.00	88	3 - 7	80	78
0.42	3/16/1/8	49	10.50	90	0 - 1	80	78
0.46	13/64x1/8	46	11.50	85	4 - 7	78	76
0.48	13/64x1/8	50½	12.00	89	4 - 8	80	78

TABLE 8.2f SPRINKLER SELECTION FOR 40' x 50' SPACING

Application Rate (in/hr)	Sprinkler Nozzle Size (in)	Pressure at Nozzle (psi)	Flow per Sprinkler (gpm)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency	
						Cool Climate (%)	Hot Climate (%)
0.28	5/32x3/32	36	5.80	89	1 & 2	76	74
0.29	5/32x3/32	40	6.11	86	5 & 10	78	76
0.31	5/32x3/32	45	6.48	88	5 & 7	79	77
0.33	5/32x3/32	50	6.84	87	2 & 3	80	78
0.36	11/64x3/32	45	7.46	89	2 & 3	77	75
0.38	11/64x3/32	50	7.87	87	1 & 2	80	78
0.41	3/16x3/32	45	8.57	86	1 & 6	76	74
0.43	3/16x3/32	49	8.95	87	4 & 8	78	76
0.49	3/16x1/8	45	10.10	88	3 & 7	74	72
0.51	3/16x1/8	50	10.60	90	0 & 1	78	76

TABLE 8.2g SPRINKLER SELECTION FOR 60' x 60' SPACING

Application Rate (in/hr)	Sprinkler Nozzle Size (in)	Pressure at Nozzle (psi)	Flow per Sprinkler (gpm)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency	
						Cool Climate (%)	Hot Climate (%)
0.18	5/32x3/32	50	5.84	82	1 & 3	76	74
0.19	11/64x3/32	40	7.03	82	0 & 2	74	72
0.21	11/64x3/32	50	7.87	82	2 & 6	75	73
0.23	3/16x3/32	45	8.57	87	3 & 7	75	73
0.27	3/16x1/8	45	10.10	82	3 & 7	74	72
0.33	13/64x1/8	55	12.50	88	3 & 4	77	75
0.35	7/32x1/8	49	13.20	88	1 & 4	74	72
0.36	7/32x1/8	51	13.40	82	4 & 8	74	72

PART IX – STATIONARY GUNS

The operation of a gun system differs from that of a sprinkler system due to the gun's high application rate. The set times are therefore much shorter to apply the required amount of water. Adequate pressure is very important in the GIANT GUN applications because of the large volume of water discharged. If the pressure is too low, the large droplets may cause crop damage. The other major difference is that two guns operating simultaneously should never operate side by side. This practice reduces the actual application rate. To design a gun system two types of application rates must therefore be calculated, the INSTANTANEOUS APPLICATION RATE and the OVERLAP APPLICATION RATE.

9.1 Instantaneous Application Rate (I.A.R.)

The actual rate at which the water is applied to the soil. This must be less than the maximum allowable by the soil.

$$\text{I.A.R. (in/hr)} = \frac{\text{gpm} \times 96.3}{\pi r^2}$$ where r = Radius of gun (ft)

9.2 Overlap Application Rate (A.R.)

The rate which is used to determine the amount of water applied to the soil over an irrigation interval. This is based on the gun spacing.

$$\text{A.R. (in/hr)} = \frac{\text{gpm} \times 96.3}{\text{Spacing (ft} \times \text{ft)}}$$

Maximum Square Spacing = Wetted Diameter x 0.60 (Wind up to 4 mph)
Wetted Diameter x 0.50 (Wind 4 to 8 mph)
Wetted Diameter x 0.40 (Wind over 8 mph)

Gun Systems are subject to poor distribution in windy conditions because of the large wetted radius and the height of throw. Higher pressures are also required to achieve proper water distribution.

NOTE: To prevent electric shock a gun should not be operated within 100 feet of a high voltage power line.

9.3 Recommended Minimum Operating Pressures for Gun Systems

As the pressure at the gun nozzle increases, the stream velocity increases breaking up the water into finer droplets. This increased stream velocity provides a larger wetted diameter which reduces the application rate. To select the proper operating pressures for a gun system, consideration must be given to soil and crop suitability versus droplet size. In most instances, large droplets are to be avoided as they cause soil compaction and may damage the crop.

Giant guns are available in various trajectory angles. The higher trajectories maximize the diameter of throw and allow for a near zero horizontal droplet velocity before they reach the crop. The lower trajectories operate better than higher trajectories in windy conditions but do not have the desirable droplet conditions. The lower trajectory guns should be operated at higher pressures than higher trajectory guns.

Table 9.1 gives the recommended minimum operating pressures of the various gun sizes.

TABLE 9.1 RECOMMENDED MINIMUM OPERATING PRESSURES FOR GUN SYSTEMS

Flow Range (gpm)	Minimum Pressure Recommended (psi)
100 - 200	60
200 - 300	70
300 - 400	75
400 - 500	80
OVER 500	90

Note: Check individual manufacturers' recommendations when using the above table.

9.4 Sample Design

Problem

A farmer near Merritt intends to grow alfalfa on a sandy loam soil. The design of his irrigation system needs to meet maximum crop water demands. For a stationary gun system what nozzle, spacing, pressure, flow per gun and interval will be required?

From: Table 1 - Alfalfa crop - effective rooting depth is 4 feet. Soil samples indicate that the rooting depth is restricted to 3 feet. The soil is therefore a limiting factor in this case. The effective rooting depth of the crop is then only 3 feet.

Table 2 - Sandy loam soil - available water storage capacity is 1.5 in/ft.
For an effective rooting depth of 3 feet, the total AWSC is 3 feet x 1.5 in/ft = 4.5 inches. This information is usually derived from soil sample analysis.

Table 3 - Availability coefficient - for alfalfa it is 50%. The amount of moisture available to the crop is 50% x 4.5 inches = 2.25 inches (maximum soil water deficit).

Table 4 - Maximum application rate for a sandy loam soil with a sod crop is 0.45 inches/hour.

Table 5 - Evapotranspiration rate in Merritt for a 2.25 inch water deficit is 0.28 in/day.

$$\text{Irrigation Interval} = \frac{\text{Maximum soil water deficit (in)}}{\text{Peak ET (in/day)}}$$

$$= \frac{2.25 \text{ in}}{0.28 \text{ in/day}} = 8 \text{ days}$$

In this example a 140' x 140' spacing was selected based on wetted diameter and field dimensions. From Table 9.2c select an average application efficiency.

Application Efficiency - 70%

$$\text{Gross Water Regquired} = \frac{\text{Water deficit (in)}}{\text{Application Efficiency (\%)}}$$

$$= \frac{2.25 \text{ in}}{0.70} = 3.21 \text{ in}$$

A stationary gun system should not be left at one location as long as a conventional sprinkler system.

Select a set time of 5 hours.

$$\text{Overlap Application Rate} = \frac{\text{Gross water required (in)}}{\text{Set time (hrs)}}$$

$$= \frac{3.21 \text{ in}}{5 \text{ hrs}} = 0.64 \text{ in/hr}$$

For the selected spacing, the Instantaneous Application Rate is 0.24 in/hr for a 5-8 mph wind (Table 9.2c). This is less than the maximum allowable by the soil of 0.45 in/hr. The application efficiency of 68.9% is also in line with the estimated earlier choice of 70%. If the application efficiency had differed significantly from 70% the net amount applied and irrigation interval would have to be recalculated.

From the 140' x 140' Table 9.2c the following information can be extracted:

Spacing	- 140' x 140'
Overlap Application Rate	- 0.64 in/hr
Nozzle Size	-0.70 in
Pressure at Nozzle	-84 psi
Flow Rate at Nozzle	-131 gpm
Wind Range	-5 - 8 mph
Application Efficiency	-69%

The following design criteria can now be used to determine the layout of the irrigation system.

The gun system consists of a 0.70 inch nozzle operating at 84 psi with a flow rate of 131 gpm. On a 140' x 140' spacing, with an overlap application rate of 0.64 in/hr, and a 5 hour set time, the gross application is 3.21 inches. The net amount applied to the crop at an application efficiency of 69% is 2.22 inches, which is enough to last for 8 days at an ET rate of 0.28 in/day.

TABLE 9.2a SELECTED SPACING 100' x 100'

Overlap Application Rate (in/hr)	Instantaneous Application Rate (in/hr)	Nozzle Size (in)	Flow per Nozzle (gpm)	Nozzle Pressure (psi)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency (%)
.55	.32	.50	56	59	79.2	6-8	66.1
.59	.26	.50	61	70	83.4	4-6	73.7
.64	.22	.50	66	82	82.6	1-3	78.1
.66	.27	.70	69	46	72.6	7-11	62.0
.68	.22	.50	71	95	85.1	3-4	79.2
.77	.37	.60	80	58	79.5	5-8	71.3
.81	.26	.71	84	64	81.9	6-9	74.5
.85	.40	.60	88	70	82.8	5-7	72.8
.86	.29	.71	89	72	81.7	5-6	67.3
.90	.30	.60	91	75	86.0	4-7	78.1
.93	.35	.60	96	84	82.7	5-8	78.1
.94	.24	.71	98	88	91.2	2-5	86.0
.95	.23	.71	99	90	93.2	2-4	88.7
.98	.26	.77	102	67	87.0	4-7	80.3
1.02	.65	.70	106	58	77.5	7-11	67.8
1.06	.35	.87	110	60	83.1	5-7	71.3
1.14	.27	.87	118	70	83.3	2-3	76.9
1.22	.35	.87	127	80	88.4	2-4	83.7
1.26	.24	.70	131	84	88.0	5-8	81.0
1.32	.33	.87	137	91	88.1	4-7	85.8
1.37	.25	.87	142	100	86.3	3-5	79.1
1.43	.33	.87	149	109	90.7	4-8	85.6
1.49	.33	.97	155	70	90.7	1-3	84.9
1.58	.60	.99	164	80	79.8	5-8	65.5
1.67	.32	.97	173	88	93.5	5-8	89.9
1.78	.37	.99	185	100	91.4	2-4	86.4
1.86	.28	.99	193	108	91.8	2-4	86.6
1.92	.49	.99	200	115	88.2	6-11	81.9
2.05	.74	1.10	213	80	72.2	9-14	60.6
2.29	.36	1.10	238	100	90.9	5-8	85.2
2.34	.39	1.20	243	70	91.2	4-5	84.4
2.41	.30	1.10	250	110	94.1	2-4	90.0
2.79	.41	1.20	290	100	95.1	5-8	91.6
3.13	.35	1.29	325	85	94.9	1-4	90.2
3.34	.75	1.29	347	98	89.2	6-9	83.9

TABLE 9.2b SELECTED SPACING 120' x 120'

Overlap Application Rate (in/hr)	Instantaneous Application Rate (in/hr)	Nozzle Size (in)	Flow per Nozzle (gpm)	Nozzle Pressure (psi)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency (%)
.41	.26	.50	61	70	74.8	4-6	64.1
.44	.22	.50	66	82	78.2	1-3	72.0
.47	.22	.50	71	95	78.3	3-4	71.3
.53	.37	.60	80	58	71.6	5-8	60.0
.56	.26	.71	84	64	76.4	6-9	63.3
.59	.40	.60	88	70	80.7	5-7	71.6
.63	.30	.60	91	75	78.4	4-7	72.9
.65	.35	.60	96	84	78.1	5-8	69.7
.68	.26	.77	102	67	77.5	4-7	70.0
.74	.35	.87	110	60	76.7	5-7	64.5
.79	.27	.87	118	70	82.5	2-3	74.8
.84	.50	.70	126	80	82.9	6-9	73.9
.85	.35	.87	127	80	89.9	2-4	87.6
.88	.24	.70	131	84	80.3	5-8	72.7
.92	.33	.87	137	91	84.6	4-7	74.8
.95	.25	.87	142	100	88.9	3-5	85.6
.96	.33	.97	143	60	86.6	3-4	80.8
1.00	.33	.87	149	109	90.7	4-8	85.1
1.03	.29	.99	154	70	91.5	4-6	86.3
1.04	.27	.87	156	118	89.2	3-6	83.0
1.16	.36	.97	173	88	85.6	5-6	78.3
1.24	.37	.99	185	100	90.3	2-4	83.3
1.29	.28	.99	193	108	89.4	2-4	84.2
1.32	.36	1.08	197	70	91.0	4-7	86.0
1.34	.49	.99	200	115	83.8	6-11	74.4
1.59	.36	1.10	238	100	88.4	5-8	85.4
1.62	.39	1.20	243	70	87.0	4-5	82.8
1.67	.30	1.10	250	110	89.6	2-4	82.1
1.94	.41	1.20	290	100	91.1	5-8	86.3
2.17	.35	1.29	325	85	88.7	1-4	80.4
2.32	.75	1.29	347	98	84.7	6-9	75.1

TABLE 9.2c SELECTED SPACING 140' x 140'

Overlap Application Rate (in/hr)	Instantaneous Application Rate (in/hr)	Nozzle Size (in)	Flow per Nozzle (gpm)	Nozzle Pressure (psi)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency (%)
.32	.22	.50	66	82	78.8	1-2	62.4
.35	.22	.50	71	95	78.0	3-4	64.2
.41	.26	.71	84	64	76.9	6-9	63.4
.48	.24	.71	98	88	76.7	2-5	60.8
.49	.23	.71	99	90	79.7	2-4	68.2
.50	.26	.77	102	67	75.2	4-7	61.2
.57	.44	.70	117	70	77.4	7-11	68.3
.58	.27	.87	118	70	75.9	2-3	69.1
.60	.33	.87	137	91	78.7	4-7	69.3
.62	.35	.87	127	80	83.1	2-4	77.0
.63	.29	.70	128	81	77.7	3-6	67.8
.64	.24	.70	131	84	76.7	5-8	68.9
.67	.50	.86	137	92	84.8	6-11	75.7
.69	.35	.86	140	96	83.1	7-11	72.8
.70	.25	.87	142	100	77.6	3-5	69.8
.73	.33	.87	149	109	74.4	4-8	64.5
.76	.33	.97	155	70	84.2	1-3	78.2
.77	.27	.87	156	118	83.6	3-7	76.5
.80	.34	.97	162	77	84.4	0	75.3
.85	.36	.97	173	88	79.0	5-6	70.0
.86	.30	.99	175	90	86.0	3-4	80.1
.90	.31	1.08	184	61	83.2	2-3	77.1
.91	.37	.99	185	100	83.9	2-4	75.0
.95	.28	.99	193	108	87.6	2-4	80.9
.97	.36	1.08	197	70	81.8	4-7	74.4
.98	.39	1.10	200	70	84.3	3-5	78.3
1.05	.74	1.10	213	80	75.1	9-14	60.7
1.18	.39	1.20	243	70	86.2	3-5	79.6
1.23	.30	1.10	250	110	90.8	2-4	87.5
1.42	.41	1.20	290	100	93.4	4-8	89.3
1.60	.35	1.29	325	85	87.7	1-4	83.4
1.70	.75	1.29	347	98	81.2	5-8	69.6

TABLE 9.2d SELECTED SPACING 160' x 160'

Overlap Application Rate (in/hr)	Instantaneous Application Rate (in/hr)	Nozzle Size (in)	Flow per Nozzle (gpm)	Nozzle Pressure (psi)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency (%)
.32	.26	.71	84	64	75.2	6-9	63.1
.37	.23	.71	99	90	77.4	2-4	63.6
.41	.34	.86	110	60	77.1	4-6	66.1
.45	.37	.86	122	72	79.2	6-9	62.1
.48	.29	.70	127	80	75.5	3-6	63.6
.52	.50	.86	137	92	80.4	6-11	69.0
.53	.25	.87	142	100	78.1	3-5	67.1
.54	.33	.97	143	60	77.7	3-4	60.8
.56	.33	.87	149	109	75.8	4-8	65.4
.58	.29	.99	154	70	77.7	4-6	68.3
.59	.27	.87	156	118	79.9	3-6	63.6
.61	.34	.97	161	76	81.2	0-1	73.6
.62	.60	.99	164	80	73.5	5-8	60.2
.65	.36	.97	173	88	78.7	5-6	65.4
.66	.30	.99	175	90	79.8	3-4	73.2
.70	.37	.99	185	100	77.9	2-4	68.7
.73	.28	.99	193	108	79.9	2-4	70.2
.74	.36	1.08	197	70	79.5	4-7	67.2
.75	.39	1.10	200	70	81.3	4-5	74.0
.89	.36	1.10	238	100	78.3	5-8	67.3
.91	.39	1.20	243	70	77.1	4-5	71.0
.94	.30	1.10	250	110	84.6	2-4	75.7
1.09	.41	1.20	290	100	88.3	5-8	83.1
1.22	.35	1.29	325	85	88.1	1-4	79.9
1.30	.75	1.29	347	98	74.1	6-9	62.5

TABLE 9.2e SELECTED SPACING 180' x 180'

Overlap Application Rate (in/hr)	Instantaneous Application Rate (in/hr)	Nozzle Size (in)	Flow per Nozzle (gpm)	Nozzle Pressure (psi)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency (%)
.29	.23	.71	99	90	72.9	2-4	63.9
.36	.37	.86	121	71	78.2	6-9	67.0
.38	.30	.86	128	80	77.0	5-10	68.1
.41	.33	.87	137	91	75.0	4-7	63.6
.42	.35	.86	140	96	79.3	7-11	69.3
.44	.33	.87	149	109	79.2	4-8	66.5
.46	.27	.87	156	118	75.6	3-7	61.1
.48	.34	.97	162	77	80.5	0-1	66.9
.51	.36	.97	173	88	78.9	5-6	66.8
.52	.30	.99	175	90	79.3	3-4	66.4
.55	.37	.99	185	100	77.2	2-4	65.3
.57	.28	.99	193	108	78.2	2-4	62.9
.59	.39	1.10	200	70	81.7	3-5	70.9
.72	.39	1.20	243	70	76.4	3-5	62.8
.74	.30	1.10	250	110	79.6	2-4	72.6
.86	.41	1.20	290	100	84.6	4-8	80.6
.97	.35	1.29	325	85	82.3	1-4	72.4

TABLE 9.2f SELECTED SPACING 200' x 200'

Overlap Application Rate (in/hr)	Instantaneous Application Rate (in/hr)	Nozzle Size (in)	Flow per Nozzle (gpm)	Nozzle Pressure (psi)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency (%)
.31	.35	.87	127	80	76.2	2-4	67.9
.33	.33	.87	137	91	72.6	4-7	60.6
.34	.33	.97	143	60	73.7	3-4	64.5
.36	.33	.87	149	109	76.4	4-8	63.2
.37	.33	.97	155	70	77.7	1-3	67.6
.39	.34	.97	161	76	78.6	0-1	66.8
.42	.32	.97	173	88	77.7	5-8	67.7
.44	.31	1.08	183	60	74.1	0-2	64.4
.45	.37	.99	185	100	78.2	2-4	63.3
.47	.36	1.08	197	70	74.3	4-7	63.3
.48	.39	1.10	200	70	80.0	4-5	68.4
.57	.36	1.10	238	100	78.0	5-8	64.1
.60	.30	1.10	250	110	80.5	2-4	68.4
.70	.41	1.20	290	100	84.6	5-8	75.4
.78	.35	1.29	325	85	80.4	1-4	70.3

TABLE 9.2g SELECTED SPACING 220' x 220'

Overlap Application Rate (in/hr)	Instantaneous Application Rate (in/hr)	Nozzle Size (in)	Flow per Nozzle (gpm)	Nozzle Pressure (psi)	Coefficient of Uniformity (%)	Wind Range (mph)	Application Efficiency (%)
.25	.35	.87	127	80	76.2	2-4	64.0
.31	.33	.97	155	70	76.6	1-3	67.0
.32	.34	.97	161	76	76.6	0-1	67.2
.34	.32	.97	173	88	76.6	5-8	60.8
.37	.37	.99	185	100	73.3	2-4	60.7
.37	.31	1.08	183	60	73.7	0-2	65.9
.38	.28	.99	193	108	73.2	2-4	60.4
.39	.36	1.08	197	70	73.6	4-7	60.0
.40	.39	1.10	200	70	75.9	4-5	62.9
.47	.36	1.10	238	100	76.5	5-8	65.0
.50	.30	1.10	250	110	78.4	2-4	61.9
.65	.35	1.29	325	85	81.4	1-4	70.0

PART X – TRAVELLING GUN SPRINKLERS

Two types of TRAVELLING GUNS are the winch type and the reel irrigator. The winch machine draws itself along on a cable anchored at the end of the field, dragging the supply hose behind it. The reel irrigator usually reels in the hose and gun as the machine itself remains stationary.

10.1 Points to Consider when Selecting Travelling Gun Sprinklers

1) High pressures are required to operate a travelling gun because of the high friction loss in the hose and driving mechanism. Total system pressure should be kept below 160 psi to minimize potentially dangerous operating conditions. A maximum pressure of one and one half times the operating pressure of the gun should be used as a guide.
2) Flows must be shut off slowly to minimize pressure surges. Travelling guns at high pressures often have high velocities which are potentially dangerous. If this flow is stopped suddenly the pressure surge generated could exceed pipe pressure rating.

10.2 Formulas Used

$$\text{Amount Applied} = \frac{\text{Flow per gun (gpm)} \times 96.3}{\text{Lane Spacing (ft)} \times \text{Travel Speed (ft/hr)}}$$

$$\text{Instantaneous Application Rate (in/hr)} = \frac{\text{gpm} \times 96.3}{\pi r^2}$$

r = Radius of Gun (ft)

10.3 Sample Design

Problem

A farmer near Merritt intends to grow alfalfa on a sandy loam soil. The design of his irrigation system needs to meet maximum crop water demands. For a travelling gun system what flow per gun, nozzle pressure, lane spacing, travel speed and interval are required?

From: Table 1 - Alfalfa crop - effective rooting depth is 4 feet. Soil samples indicate that the rooting depth is restricted to 3 feet. In this case the soil depth is therefore a limiting factor. The effective rooting depth is then only 3 feet.

Table 2 - Sandy loam soil - available water storage capacity is 1.5 in/ft. For an effective rooting depth of 3 feet, the total AWSC is 3 ft x 1.5 in/ft = 4.5 inches. This information is usually derived from soil sample analysis.

Table 3 - Availabiltiy coefficient - for alfalfa it is 50%. The amount of water available to the crop is 50% x 4.5 inches = 2.25 inches (Maximum soil water deficit).

Table 4 - Maximum application rate for a sandy loam soil with a sod crop is 0.45 inches/hour.

Table 5 - Evapotranspiration rate in Merritt for a 2.25 inch water deficit is 0.28 in/day.

$$\text{Irrigation Interval} = \frac{\text{Maximum soil water defecit (in)}}{\text{Peak ET (in/day)}}$$

$$= \frac{2.25 \text{ in}}{0.28 \text{ in/day}} = 8 \text{ days}$$

Next calculate the gross amount of water required. For travelling guns, assume an application efficiency of 72%. Specific application efficiencies have not been determined at this time.

$$\text{Gross water required} = \frac{\text{Maximum soil water deficit (in)}}{\text{Application efficiency (\%)}}$$

$$= \frac{2.25 \text{ in}}{0.72} = 3.13 \text{ in}$$

From: Table 10.1 - Once the gross water required has been determined Table 10.1 can be used to select the gpm, lane spacing and travel speed. The size of the field will help to determine which size gun should be selected. As a rough guide multiply the acreage of the field by the irrigation allotment in the area to obtain the total gpm required.

In this example assume that a 300 gpm gun is required.

For a gross water application of 3.13 inches the following information can be taken from Table 10.1.

Flow Rate - 300 gpm

Lane Spacing - 220 ft

Travel Speed - Approximately 40 ft/hr

From: Table 9.1 - A gun operating at 300 gpm requires at least 75 psi for proper stream breakup. The manufacturers charts should be used to determine the actual pressure requirements for a 220 ft lane spacing and a 300 gpm gun. Manufacturers'

recommend a maximum lane spacing of 60% of the wetted diameter. The minimum wetted diameter for a 220 ft lane spacing should be $\frac{220 \text{ ft}}{0.60} = 366$ ft.

From: Table 10.2 - The estimated maximum instantaneous application rate for a 300 gpm part circle gun operating at 180° arc is 0.54 in/hr. This is slightly higher than the 0.45 in/hr which is allowable by the soil. To lower the application rate the part circle gun must then cover a larger area than achieved by the 180° arc.

The area required = $\frac{\text{Flow of Nozzle (gpm) x 96.3}}{\text{Application Rate (in/hr)}}$

For 0.45 in/hr the gun area must be = $\frac{300 \text{ x } 96.3}{0.45 \text{ in/hr}}$

$= 64{,}220 \text{ ft}^2$

The area covered by a full circle gun is equal to πr^2 = Gun radius for Table 10.2.

Full circle gun area = $\pi \text{ x } (185)^2 = 107{,}520 \text{ ft}^2$

Therefore, the percentage covered by the part circle gun must be:

$\frac{64{,}200 \text{ ft}^2}{107{,}520 \text{ ft}^2} = 0.60$ or 60%

The arc required is 60% of 360° which is 216°.

The following design criteria can now be used to determine the layout of the irrigation system.

The travelling gun system consists of a 300 gpm gun with a minimum nozzle pressure of 75 psi. If a part circle gun is used the minimum arc must be 206° in order to keep the application rate at 0.45 in/hr. The gun should be operated on a 220 ft lane spacing at a travel speed of 40ft/hr. The gross water application is 3.13 inches of which 2.25 inches is applied to the crop at an application efficiency of 72%. The irrigation interval is 8 days based on the ET rate of 0.28 in/day.

TABLE 10.1 DEPTH OF WATER APPLIED BY TRAVELLING GUNS (INCHES)

Flow per Gun (gpm)	Lane Spacing (ft)	Travel Speed (ft/hr)								
		20	30	40	60	80	100	120	150	180
100	120	4.01	2.68	2.00	1.33	1.00	.80	.67	.54	.43
	135	3.56	2.38	1.78	1.18	.89	.71	.59	.48	.39
	150	3.21	2.14	1.60	1.07	.80	.64	.54	.43	.36
150	135	5.35	3.57	2.68	1.78	1.34	1.07	.89	.71	.59
	150	4.82	3.21	2.41	1.61	1.20	.96	.80	.64	.54
	165	4.37	2.92	2.19	1.46	1.09	.88	.73	.58	.49
	180	4.01	2.68	2.00	1.34	1.00	.80	.67	.54	.45
200	150	-	4.28	3.21	2.14	1.61	1.28	1.07	.86	.71
	165	5.83	3.89	2.92	1.95	1.46	1.17	.97	.78	.65
	180	5.35	3.56	2.68	1.78	1.34	1.07	.89	.71	.59
	200	4.81	3.21	2.40	1.60	1.20	.96	.80	.64	.54
250	160	-	5.01	3.76	2.50	1.88	1.50	1.25	1.00	.84
	180	-	4.46	3.34	2.23	1.67	1.34	1.11	.89	.74
	200	-	4.00	3.00	2.00	1.50	1.20	1.00	.80	.67
	220	5.47	3.65	2.74	1.82	1.37	1.09	.91	.73	.61
300	180	-	5.35	4.01	2.68	2.00	1.00	1.34	1.07	.89
	200	-	4.81	3.61	2.40	1.81	1.44	1.20	.96	.80
	220	-	4.37	3.28	2.19	1.64	1.31	1.09	.88	.73
	240	-	4.00	3.00	2.00	1.50	1.20	1.00	.80	.67
350	180	-	-	4.68	3.12	2.34	1.87	1.56	1.25	1.04
	200	-	5.61	4.21	2.81	2.11	1.68	1.40	1.12	.94
	220	-	5.11	3.83	2.55	1.92	1.53	1.28	1.02	.85
	240	-	4.68	3.51	2.34	1.76	1.40	1.17	.94	.78
400	200	-	-	4.81	3.21	2.41	1.92	1.60	1.28	1.07
	220	-	5.84	4.37	2.92	2.19	1.75	1.46	1.17	.97
	240	-	5.35	4.01	2.68	2.00	1.60	1.34	1.07	.89
	260	-	4.94	3.70	2.47	1.85	1.48	1.23	.99	.82

TABLE 10.1 (cont'd) DEPTH OF WATER APPLIED BY TRAVELLING GUNS (Inches)

Flow per Gun (gpm)	Lane Spacing (ft)	Travel Speed (ft/hr)								
		40	50	60	80	100	120	140	160	180
450	200	5.42	4.33	3.61	2.71	2.17	1.81	1.55	1.35	1.20
	220	4.92	3.94	3.28	2.46	1.97	1.64	1.41	1.23	1.09
	240	4.51	3.61	3.00	2.26	1.81	1.50	1.29	1.13	1.00
	260	4.17	3.33	2.78	2.08	1.67	1.39	1.19	1.04	.93
500	220	5.47	4.38	3.64	2.74	2.18	1.82	1.56	1.37	1.22
	240	5.01	4.01	3.34	2.51	2.00	1.67	1.43	1.25	1.11
	260	4.62	3.70	3.09	2.31	1.85	1.54	1.32	1.16	1.03
	280	4.30	3.44	2.87	2.15	1.71	1.43	1.23	1.07	.95
550	220	6.01	4.81	4.01	3.00	2.40	2.00	1.71	1.50	1.34
	240	5.51	4.41	3.67	2.76	2.20	1.84	1.58	1.38	1.23
	260	5.09	4.07	3.40	2.55	2.04	1.70	1.46	1.27	1.13
	280	4.73	3.78	3.15	2.36	1.89	1.58	1.35	1.18	1.05
600	240	6.02	4.82	4.01	3.00	2.40	2.00	1.72	1.50	1.34
	260	5.55	4.44	3.70	2.78	2.22	1.85	1.59	1.39	1.23
	280	5.15	4.13	3.44	2.58	2.06	1.72	1.47	1.29	1.15
	300	4.81	3.85	3.21	2.41	1.92	1.60	1.38	1.20	1.07
650	240	-	5.21	4.35	3.26	2.60	2.17	1.86	1.63	1.45
	260	6.02	4.82	4.01	3.00	2.40	2.00	1.72	1.50	1.34
	280	5.59	4.47	3.73	2.79	2.24	1.86	1.60	1.40	1.24
	300	5.22	4.17	3.48	2.61	2.09	1.74	1.49	1.30	1.16
700	260	-	5.19	4.32	3.24	2.59	2.16	1.85	1.62	1.44
	280	6.02	4.82	4.01	3.00	2.40	2.00	1.72	1.50	1.34
	300	5.62	4.49	3.75	2.81	2.24	1.87	1.61	1.40	1.25
	320	5.27	4.21	3.51	2.63	2.10	1.75	1.50	1.32	1.17

10.4 Maximum Instantaneous Application Rate

Table 10.2 is to be used as a guide to determine the maximum application rate of a travelling gun. The values are based on a part circle gun which is operating in minimal wind conditions. The application rate of a part circle gun is greater than a full circle gun of the same capacity. In this case use a 180^{o} arc so that a full circle gun will have half the application rate of the part circle gun. When operating in windy conditions the application rates will be substantially affected. The gun radius shown is an average value taken from the manufacturers specifications.

$$\text{Maximum Instantaneous Application Rate (in/hr)} = \frac{\text{Flow per (gpm)} \times 96.3}{(\pi r^2/2)}$$

where r = Gun Radius

TABLE 10.2 MAXIMUM INSTANTANEOUS APPLICATION RATE FOR PART CIRCLE GUNS (Inches per Hour)

Flow per Gun (gpm)	Gun Radius (ft)	*Maximum Instantaneous Application Rate (in/hr)
100	130	.36
150	150	.41
200	160	.48
250	175	.50
300	185	.54
350	190	.59
400	200	.61
450	210	.63
500	215	.66
550	220	.70
600	225	.73
650	230	.75
700	235	.78

* Based on a part circle gun operating over a 180^{o} arc.

PART XI – CENTER PIVOT IRRIGATION

CENTER-PIVOT irrigation systems consist of trussed piping networks supported by towers on wheels. The system travels in a circle or part circle around a pivot point. Center-pivot systems are usually a permanent set installation that require only starting and stopping. There are systems available that can be moved from one location to another.

11.1 Points to Consider when Selecting Center-Pivot Systems

Center-pivot systems use spray nozzles, sprinklers or guns to apply the water. The outside radius of the pivot must apply as much water as at the pivot point but in a much shorter time period. The application rates at the outer limits therefore must be much higher than at the pivot point. Application rates may be increased by nozzle sizing and/or spacing from the pivot point to the end of the line. These are precalculated by manufacturers' computerized recommendation. A big gun is usually used at the end of the line to give the pivot a greater effective radius.

11.2 Formulas Used

$$\text{Area Irrigated (acres)} = \frac{\pi R^2 \times P}{43560}$$

R=Effective Radius of Pivot(ft)
P=Percentage of Full Circle Irrigated (%)

$$\text{Amount Applied (in)} = \frac{96.3 \times \text{gpm} \times N}{\pi R^2}$$

N=Rotation Speed (hrs/revolution)

$$\text{Quantity of Water Required (gpm)} = \frac{18.90 \times \text{Peak ET} \times \text{Area (ac)}}{\text{Application Efficiency (\%)}}$$

$$\text{Maximum Application Rate (in/hr)} = \frac{122.5 \times Q}{R \times r}$$

Q = gpm of Center-pivot
r = Radius of Throw of the end Sprinklers on the Pivot (ft)
R = Effective Radius of Pivot (ft)

Figures and tables are provided on the following pages to assist in the design.

11.3 Sample Design

Problem

A farmer near Merritt intends to grow alfalfa on a sandy loam soil. The design of his irrigation system needs to meet maximum crop water demands. For a center-pivot irrigation system what total flow (gpm), pressure, rotation speed, radius of pivot and interval will be required?

From: Table 1 - Alfalfa crop - effective rooting depth is 4 feet. Soil samples indicate that the rooting depth is restricted to 3 feet. The soil is therefore a limiting factor in this case. The effective rooting depth is only 3 feet.

Table 2 - Sandy loam soil - available water storage capacity is 1.5 in/ft.
The total AWSC is then 3 ft x 1.5 in/ft = 4.5 inches.
This information is usually derived from soil sample analysis.

Table 3 - Availability coefficient - for alfalfa it is 50%. The amount of water available to the crop is 50% x 4.5 inches = 2.25 inches (Maximum soil water defecit).

Table 4 - Maximum application rate for sandy loam soil with a sod crop of 0.45 in/hr.

Table 5 - Evapotranspiration rate in Merritt for a 2.25 inch maximum soil water deficit is 0.28 in/day.

$$\text{Irrigation Interval} = \frac{\text{Maximum soil water deficit(in)}}{\text{Peak ET (in/day)}}$$

$$= \frac{2.25 \text{ in}}{0.28 \text{ in/day}} = 8 \text{ days}$$

For a pivot system assume an application efficiency of 72%

$$\text{The gross water required} = \frac{\text{Water deficit (in)}}{\text{Application efficiency (\%)}}$$

$$= \frac{2.25 \text{ in}}{0.72} = 3.13 \text{ in}$$

Gross water required on a daily basis would be $\frac{0.28}{0.72}$ in = 0.39 in/day.

Before a pivot system can be designed, a plan of the field size and shape is required. In this case assume an effective radius of 1000'.

From : Table 11.1 - Determine the gpm required for an effective radius of 1000' and a gross daily requirement of 0.39 inches. Interpolating between 0.37 and 0.44 inches it is determined that 530 gpm will be required.

Note: The 0.39 inches applied is based on a rotation time of 24 hours. In order to apply the quantity of water which the soil can hold a rotation time of 8 days is required. (Maximum allowable irrigation interval).

In order to obtain an appropriate rotation time for the center-pivot, the maximum application rate of the pivot must be determined.

From: Figure 11.1 determine the maximum application rate.

Effective radius of pivot = 1000 ft (does not include an end gun). If an end gun was included the radius of the end gun must be subtracted.

Flow = 530 gpm

$$\frac{\text{Flow of pivot (gpm)}}{\text{Effective Radius of pivot (ft)}} = \frac{530}{1000} = 0.53 \text{ gpm/ft}$$

The effective radius of throw of the last sprinkler on the pivot must also be known.(Not including the end gun.) In this example assume a radius of throw of 70 ft.

Therefore the maximum application rate of the pivot is 0.94 in/hr from Figure 11.1.

The maximum allowable application rate by the soil is only 0.45 in/hr. Although the application rate of the pivot cannot be altered, the duration of application can be by changing the travel speed.

From Table 11.2 the maximum application rate allowable can be calculated.

$$\frac{\text{Application Rate of Pivot}}{\text{Allowable application rate of soil}} = \frac{0.94 \text{ in/hr}}{0.45 \text{ in/hr}} = 2.10 \text{ (Multiplication factor)}$$

From: Table 11.2 - For a multiplication factor of 2.10 the duration of application should not exceed 25 minutes. The wetted diameter of the sprinkler at the end of the pivot is 140 feet (2 x 70 ft.)

$$\text{Speed of Rotation} = \frac{\text{Wetted Diameter}}{\text{Time}} = \frac{140 \text{ ft}}{25 \text{ min}} = 5.6 \text{ ft/min}$$

(speed of the outside circumference of the pivot)

Maximum Rotation time $= \frac{\text{Circumference of Pivot}}{\text{Speed of Rotation}} = \frac{2\pi R}{5.6}$

$= \frac{2\pi \times 1000}{5.6} = 1121$ Minutes $= 19$ hours

Note: For a flow capacity of 530 gpm the pivot should be operating continuously, regardless of speed of rotation.

The design parameters for the pivot are as follows:

The pivot has a radius of 1000 ft and a flow rate of 530 gpm. The pivot would make one revolution every 19 hours this provides a short enough application duration so as not to exceed the maximum design application rate of the soil. The pressure requirement of the pivot must be obtained from manufacturers' specifications. The pivot must be operated continuously to meet the evapo-transpiration required on a daily basis. If intermittent operation is desired the system must be redesigned for a higher flow rate.

Table 11.1

DETERMINATION OF MAXIMUM APPLICATION RATES FOR CENTER-PIVOTS

Sprinkler Radius = Wetted Radius of largest sprinkler on pivot, excluding the end gun.

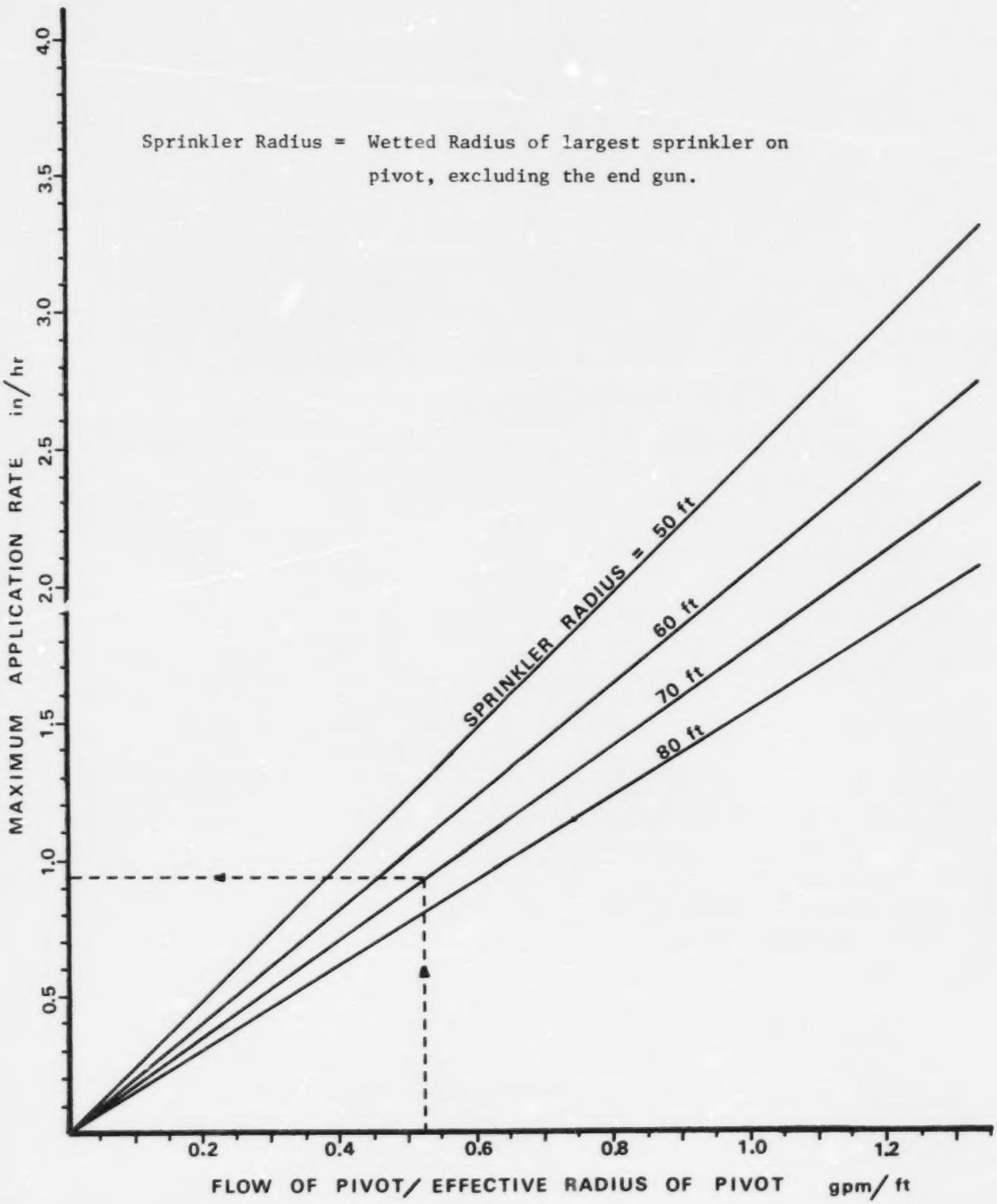


TABLE 11.2 AMOUNT APPLIED PER DAY BY CENTER - PIVOT SYSTEMS (INCHES) (Rotation Time = 24 Hours)
N = 24

Eff. Radius (ft)	Area (acres)	Pivot flow (gpm)										
		200	300	400	500	600	700	800	900	1000	1100	1200
200	2.9	3.67	5.52	-	-	-	-	-	-	-	-	-
300	6.5	1.63	2.45	3.27	4.09	4.90	5.72	-	-	-	-	-
400	11.5	.92	1.38	1.84	2.30	2.75	3.22	3.68	4.14	4.60	5.06	5.52
500	18.0	.59	.88	1.18	1.47	1.76	2.06	2.35	2.65	2.94	3.24	3.53
600	26.0	.41	.62	.82	1.02	1.23	1.43	1.63	1.84	2.04	2.25	2.45
700	35.3	.30	.45	.60	.75	.90	1.05	1.20	1.35	1.50	1.65	1.80
800	46.2	.23	.34	.46	.57	.69	.80	.92	1.03	1.15	1.26	1.38
900	58.4	.18	.27	.36	.45	.54	.64	.73	.82	.91	1.00	1.09
1000	72.1	.15	.22	.29	.37	.44	.51	.59	.66	.74	.81	.88
1100	87.3	.12	.18	.24	.30	.36	.43	.49	.55	.61	.67	.73
1200	103.9	.10	.15	.20	.26	.31	.36	.41	.46	.51	.56	.61
1300	121.9	.09	.13	.17	.22	.26	.30	.35	.39	.44	.48	.52
1400	141.4	.08	.11	.15	.19	.23	.26	.30	.34	.38	.41	.45
1500	162.3	.07	.10	.13	.16	.20	.23	.26	.29	.33	.36	.39
1600	184.6	.06	.09	.11	.14	.17	.20	.23	.26	.29	.32	.34

11.4 Guide in Determining the Maximum Application Rates Allowable by a Center-Pivot Irrigation System

Most soils permit a much higher application rate during the first one or two hours of water application as compared to an eight or twelve hour period. The maximum application rates shown in Table 4 are based on long settings of twelve hours. Table 11.2 is a guide in adjusting Table 4, maximum design application rates, to an appropriate value for short duration applications.

TABLE 11.3 MAXIMUM APPLICATION RATE MULTIPLICATION FACTORS ALLOWABLE FOR SHORT DURATIONS (Tentative estimates only)

Duration of Water Application (min.)	Multiplication Factor
15	2.5
20	2.25
30	2.0
60	1.75
90	1.50
120	1.25

PART XII – TRICKLE IRRIGATION

12.1 Introduction

TRICKLE IRRIGATION (drip irrigation) is the daily application of water to a plant, in an amount sufficient to replenish the water used during the past day, plus an excess to leach harmful salts from the root zone. Terminology used is gallons per plant per day, rather than inches per application as in sprinkler irrigation. A trickle system utilizes an EMITTER to provide each plant with the daily water requirement. The water is distributed throughout the root zone from point source emitters by lateral and vertical moisture movement through the soil. Spray emitters use a spray pattern to distribute the water throughout the root zone.

Note: - Proper operation of trickle irrigation systems requires constant monitoring of soil moisture levels with tensiometers or other equipment.

- Trickle irrigation systems are very susceptible to elevation changes unless pressure compensating emitters are used.

12.2 Crop Water Requirement

Gallons per Plant per Day (G/P/D)

$$G/P/D = 0.623 \times E.T. \times 0.75 \times A \times K$$

where $0.623 = \frac{27,152 \text{ gallons/acre-in.}}{43,560 \text{ ft}^2/\text{acre}}$

E.T. = peak evapotranspiration rate for location (Table 12.1)

0.75 = a correction factor for peak E.T. applied to Trickle Irrigation.

A = Area per plant (ft^2)

K = CROP COEFFICIENT FACTOR (Table 12.2)

NOTE: 1) The maximum crop coefficient factor (K) should be used in determining the water use by the crop. The trickle system must be designed to supply the plants peak water requirement on a daily basis. The application time of the system can then be shortened to adjust for plant growth stages or seasonal requirements that have lesser water useage.

2) An additional water requirement of 10% should be provided to the plants to allow for leaching of salts away from the plant root zone.

3) A minimum of 40% of the existing ROOT AREA must be wetted when converting from sprinkler irrigation to trickle irrigation. The lateral spread from a point source emitter can be obtained from Table 12.3. For wetted diameters from spray type emitters see Table 12.4 or manufacturer's specifications.

4) In established low density orchard plantings and very light soil conditions, six or more point source emitters per tree may be required to distribute the water effectively around the tree.

12.3 Trickle Irrigation System Design Parameters

NOTE: 1) The pressure variation within a ZONE should not exceed ± 10% of the selected emitter operating pressure.

2) Reference to manufacturer's specifications and design information for the actual emitter selected should be made to verify design procedures.

12.3.1 Spray Emitter Design

An orchardist has 10 acres of loam soil in an area where the peak E.T. is 0.25 in./day and an irrigation allotment of 6 gpm per acre. Calculate the required gallons per plant per day, number of emitters per plant, emitter flow rate, total flow rate and application time.

Base Data for Orchard

Emitter used	- Spray type emitter
Row length	- 400 ft.
Tree spacing	- 10 ft. x 16 ft.
Area per plant (A)	- 160 $ft.^2$
Trees per row	- 40
Total number of rows	- 65
Crop coefficient (mature apple orchard) Table 12.2	- 0.90
Peak E.T. (Table 12.1)	- 0.25 in./day
Total Irrigation District Allotment	- 60 gpm
Soil Type	- loam
Emitter operating pressure	- 15 psi

G/P/D = 0.623 x (0.25) x (0.75) x (160) x (.90)

= 16.8 gallons/plant/day

Plus 10% leaching = 1.7 G/P/D

TOTAL = 18.5 G/P/D

From Table 12.4 - Select 0.04 inch spray emitters operating at 15 psi, 9.0 gph discharge, with a wetted radius of 5.9 ft. for a 180° spray pattern. Two emitters will be installed per tree, one on each side for a wetted diameter of 11.8 ft.

Water supplied per row per hour = trees/row x gph/tree
= 40 x (2 x 9.0 gph/tree)
= 720 gph/row

Number of rows per zone = $\frac{\text{Water allotment x 60 min./hr.}}{\text{gph/row}}$
= $\frac{60 \text{ gpm x } 60 \text{ min./hr.}}{720 \text{ gph/row}}$
= 5 rows/zone

Number of zones = $\frac{\text{total rows}}{\text{rows/zone}}$
= $\frac{65}{5}$
= 13 zones

Gallons required per row per day = G/P/D x trees/row
= 18.5 x 40
= 740 gallons/row/day

Application time per zone = $\frac{\text{gallons/row/day}}{\text{gph/row}}$
= $\frac{740}{720}$ = 1.03 hr./zone/day
= 1 hr. and 2 min. per zone per day

Total hours of irrigation per day = 13 zones x 1 hr. and 2 min./ zone/day
= 13 hours 26 min./day

The following design criteria can be used in the layout of the trickle irrigation system:
The 10 acre orchard is divided into 13 zones with 5 rows per zone. At peak requirements each tree will receive 18.5 gallons per day from two 0.04 inch, 180° spray emitters that are operating at 15 psi. The total irrigation time per zone is 1 hour 2 min. with a total daily operation of 13 hours 26 minutes.

12.3.2 Point Source Emitter Design

A raspberry grower has 10 acres of loamy sand in an area where the peak E.T. is 0.25 in./day with an Irrigation District allotment of 6 gpm per acre. Calculate gallons per plant per day, number of emitters per plant, emitter flow rate, total flow rate and application time.

Base Data for Raspberry Field

Emitter used	- 1 gph orifice emitter
Row length	- 200 ft.
Plant spacing	- 2½ ft x 10 ft.
Plant area - (A)	- 25 ft.^{2}
Plants per row	- 80
Number of rows in field	- 218
Peak E.T. (Table 12.1)	- 0.25 in./day
Total irrigation district allotment	- 60 gpm
Emitter operating pressure	- 15 psi
Soil type	- loam
Crop coefficient (Table 12.2)	- 0.60

G/P/D = 0.623 x (0.25) x (0.75) x (25) x (0.60)

= 1.8 gallons per plant per day

10% leaching = 0.18 G/P/D

Total = 2.0 G/P/D

Select 1 gph emitters operating at 15 psi. From Table 12.3, the lateral spread of water in a loam soil is 5 ft. The emitters should be spaced every 5 ft. to provide a continuous wetted strip along the raspberry rows.

The maximum pressure variation along the lateral cannot exceed 10%. To ensure that the friction loss along the line is not excessive, check Table 12.5A. The designer can overcome excessive friction losses by either i) increasing lateral pipe size

ii) decreasing the row length

iii) increasing inlet pressure and using pressure compensating emitters.

From Table 12.5A, for 200 ft. of 10 mm hose with snap-on emitters every 5 ft. the friction loss is 1.5 psi. For this situation the HEADER line must be designed for negligible friction loss or a 15 mm lateral hose should be used.

Water supplied per row per hour $= \frac{\text{ft./row x gph/emitter}}{\text{emitter spacing}}$

$= \frac{200 \times 1}{5}$

$= 40$ gph/row

Number of rows per zone $= \frac{\text{Water allotment x 60 min./hr.}}{\text{gph/row}}$

$= \frac{60 \text{ gpm} \times 60 \text{ min./hr.}}{40 \text{ gph/row}}$

$= 90$ rows per zone

Number of zones $= \frac{218 \text{ rows}}{90 \text{ rows/zone}}$

$= 2.4$ or 3 zones

Since one zone would contain only 38 rows compared to 90 rows for the other two zones the system should be balanced by setting up 3 zones of 73 rows each.

Required gallons per row per day $=$ G/P/D x plants/row

$= 2.0 \times 80$

$= 160$ gal/row/day

Application time per zone per day $= \frac{\text{gal/row/day}}{\text{gph/row}}$

$= \frac{160}{40} = 4.0$ hours /day

$= 4$ hours/ zone/day

Total hours of irrigation per day $= 3$ zones x 4.0 hrs./zone/day

$= 12$ hours/day

The following design criteria can now be used in the layout of the trickle irrigation system:

The 10 acre field is divided into three zones of 73 rows per zone. At peak requirements each plant will receive 2.0 gallons per day from one 1 gph emitter supplying two plants (emitter spacing 5 ft.) operating at 15 psi. Total irrigation time for each zone is 4 hours with a total daily operating time of 12 hours.

12.3.3 Line Source Design (Continuous tape system)

A strawberry grower has 10 acres of loam soil in an area where the peak E.T. is 0.25 in./day and an irrigation district allotment of 6 gpm per acre. Calculate the gallons per plant per day, line source hose flow rates, total flow rate and application time.

Base Data for Strawberry Field

Emitter used	- Bi-wall (12 x 60) line source lateral
Row length	- 400 ft.
Plant spacing	- 1 ft. x 4 ft.
Plant area (A)	- 4 ft.^{2}
Plants per row	- 400
Number of rows in field	- 272
Peak E.T. (Table 12.1)	- 0.25 in./day
Crop coefficient (Table 12.2)	- 0.75
Total Irrigation District allotment	- 60 gpm
Soil type	- loam

G/P/D = 0.623 x 0.25 x 0.75 x 4 x 0.75
= 0.35 gallons per plant per day
10% leaching = 0.04 G/P/D
Total = 0.39 G/P/D

The maximum pressure variation along a line source lateral is 10%. A 10 psi operating pressure allows for a 1 psi pressure differential within the zone. (A 5 psi operating pressure will only allow a ½ psi pressure differential). For a plant spacing of 1 ft., a 12 x 60 Bi-wall continuous tape lateral is required.

From Table 12.6B - At a 10 psi operating pressure the maximum tubing length cannot exceed 200 ft. to stay within the 1 psi allowable pressure difference throughout the zone.

From Table 12.6A - The flow delivered by a 200 ft. length of 12 x 60 Bi-wall tubing operating at 10 psi is 1 gpm.

$$\text{Water supplied per row per hour} = \frac{1 \text{ gpm}}{200 \text{ ft. length}} \times 400 \frac{\text{ft.}}{\text{row}} = \frac{2 \text{ gpm}}{\text{row}}$$

$$= \frac{2 \text{ gpm}}{\text{row}} \times \frac{60 \text{ min.}}{\text{hr.}} = \frac{120 \text{ gph}}{\text{row}}$$

NOTE: A header is required through the middle of the 400 ft. rows to allow for two 200 ft. lengths of Bi-wall, one to each side of the header.

$$\text{Number of rows per zone} = \frac{\text{Allotment}}{\text{gph/row}} \times 60 \text{ min./hr.}$$

$$= \frac{60 \text{ gpm} \times 60 \text{ min./hr.}}{120 \text{ gph/row}}$$

$$= 30 \text{ rows/zone}$$

Number of zones $= \frac{\text{rows}}{\text{rows/zone}}$

$= \frac{272}{30}$

= 9 zones & 2 rows (10 zones required)

(10 zones of approximately 27 rows per zone)

Required gallons per row per day = G/P/D x plants/row

= 0.39 x 400

= 156 gallons/row/day

Application time per zone per day $= \frac{\text{gal/row/day}}{\text{gph/row}}$

$= \frac{156 \text{ gallons/row/day}}{120 \text{ gph/row}}$

= 1.3 hours/zone/day

= 1 hour 18 minutes/zone/day

Total hours of irrigation per day = 10 zones x 1 hour 18 minutes/zone/day

= 13 hours/day

The following design criteria can now be stated in the layout of the irrigation system:

The 10 acre strawberry field is divided into 10 zones, with headers running through the middle of the 400 foot rows. Bi-wall 12 in. x 60 in. x 200 ft. in length operating at 10 psi supply each plant with 0.39 gallons per day. The operation time per zone is 1 hour, 18 minutes with a total daily operating time of 13 hours.

12.4 Lateral (Emitter) Line Design

The maximum pressure variation within a zone should not exceed ± 10% of the selected emitter operating pressure.

Therefore: Emitter line friction loss + header line friction loss + elevation difference must not exceed ± 10% of the selected operating pressure.

The friction loss in the emitter line must therefore not exceed 10% of the selected operating pressure to allow for some friction loss in the header line. During preliminary design the emitter line friction loss should be kept within 10% of the operating pressure.

12.4.1 Spray Emitter Lateral Line Selection

1) Calculating Friction Loss Using Average Flow Per Foot (AFPF)

The pressure drop along a spray emitter lateral can be calculated using Tables 12.10 - 12.16. The average flow per foot (AFPF) must first be calculated.

(i) $$\text{AFPF} = \frac{\text{number of emitters/row} \times \text{emitter flow rate (gph)}}{\text{row length}}$$

If the AFPF is less than one gallon per hour per foot, follow example 2 under the point source emitter lateral line section (12.4.2).

For AFPF greater than one gallon per hour per foot or lateral line sizes larger than 1" the following methods can be used.

2) Calculating friction loss when AFPF is greater than one gallon per hour per foot.

In this situation divide AFPF by 2. Use this reduced figure to determine lateral size and "Total Pressure Loss" from the respective graph (Tables 12.10 - 12.16). Multiply this loss figure by 4 to obtain actual friction loss for the emitter line.

Example:

An orchard with a 10 ft. x 16 ft. tree spacing has rows 200 ft. long. A spray emitter system consists of two 8 gph emitters per tree. The total number of emitters per row is therefore 2 emitters/tree x 20 trees/row = 40 emitters/row.

$$\text{AFPF} = \frac{40 \text{ emitters/row} \times 8.0 \text{ gph/emitter}}{200 \text{ ft./row}} = 1.6 \frac{\text{gph}}{\text{ft.}}$$

From Table 12.14 - (Use half of 1.6 gph/ft. or 0.80 gph/ft.)
The pressure loss for 1.02 I.D. hose, 200 ft. long with a flow of 0.80 gph/ft. is 0.22 psi.
The actual loss in the emitter line is then 0.22 psi x 4 = 0.88 psi. for a flow of 1.6 gph/ft. for 1.02 I.D. hose 200 ft. long.

3) Calculating friction loss for lateral sizes larger than 1"

The following formula can be used to calculate lateral line friction loss for pipe sizes larger than 1" in diameter:

(ii) Friction loss in lateral line =

$$\text{friction loss per 100 ft} \times \frac{\text{(emitter line length)}}{\text{100 ft}} \times 0.37 + 30\%$$

Example:

An emitter line is to supply 25 trees on a 10 ft. spacing. There are two 9 gph spray emitters per tree. The total length of the emitter (lateral) line is 250 ft.

$$\text{Flow in lateral line} = \frac{\text{2 emitters/tree x 9 gph/emitter x 25 trees}}{\text{60 minutes/hr.}} = 7.5 \text{ gpm}$$

Friction loss per 100 ft. of 1¼" polyethylene for 7.5 gpm is = 0.42 psi/100 ft. (from Table 13.6)

Friction loss in the emitter line is =

$$\left(0.42 \text{ psi per 100 ft. of 1¼" poly} \times \frac{250 \text{ ft.}}{100 \text{ ft.}} \times 0.37\right) = 0.38 \text{ psi}$$

An additional loss of 30% due to barb allowance = 0.11 psi

Total loss in emitter line = 0.49 psi

4) Calculating friction loss for lateral lines made up of two different pipe sizes.

When a lateral line is made up of two different pipe sizes (50% each), the friction loss can be calculated as follows:

a) Calculate the friction loss for the entire lateral length for the larger pipe size using the total flow.
b) Then calculate the friction loss for one half the flow in 50% of the lateral length for the larger pipe size.
c) Then calculate the friction loss for one half the flow in 50% of the lateral length for the smaller pipe size.
d) The total friction loss in the lateral line will then be: a - b + c.

Example:

An emitter line is to supply 25 trees on a 10 ft. spacing. There are two 9 gph spray emitters per tree. The total length of the lateral line is 250 ft. We wish to use 50% 1¼" poly and 50% 1" poly.

$$\text{Flow in lateral line} = \frac{\text{2 emitters/tree x 9 gph/emitter x 25 trees}}{\text{60 minutes/hr.}} = 7.5 \text{ gpm}$$

Calculation (a) Friction loss in a 250 ft. lateral of 1¼" poly for an inlet flow of 7.5 gpm is 0.49 psi (from example in section 3, page 55).

Calculation (b) Friction loss per 100 ft. of 1¼" poly for a flow of 3.75 gpm is 0.12 psi/100 ft. (from Table 13.6) Friction loss in a 125 ft. lateral of 1¼" poly for an inlet flow of 3.75 gpm is: (using equation (ii) from section 3, page 55).

$$(0.12 \text{ psi per 100 ft. of 1¼" poly}) \times \frac{125 \text{ ft.} \times .037}{100 \text{ ft.}} = 0.055 \text{ psi}$$

Plus 30% emitter barb allowance = 0.017 psi

Total loss in lateral = 0.073 psi

Calculation (c) Friction loss per 100 ft. of 1" poly for a flow of 3.75 gpm is 0.45 psi/100 ft. (From Table 13.6) Friction loss in a 125 ft. lateral of 1" poly for an inlet flow of 3.75 gpm is: (using equation (ii) from section 3 , page 55).

$$\frac{(0.45 \text{ psi per 100 ft. of 1" poly}) \times 125 \text{ ft.} \times 0.37}{100 \text{ ft.}} = 0.21 \text{ psi}$$

Plus 30% emitter barb allowance = 0.06 psi

Total loss in lateral = 0.27 psi

Calculation (d) The friction loss in a lateral line made up of 50% 1¼" poly and 50% 1" poly for this example is:
0.49 psi - 0.07 psi + 0.27 psi = 0.69 psi

12.4.2 Point Source Emitter Lateral Line Selection

The pressure loss along a lateral can be obtained from charts provided by the emitter manufacturers or calculated using friction data supplied by the lateral tubing manufacturers. Two different methods using charts contained in this design manual are shown in the following examples.

From example 12.3.2, the raspberry field is on a 2½ ft. x 10 ft. planting with row lengths of 200 ft. Point source emitters, discharging 1 gph at 15 psi, are to be spaced every 5 ft. along the lateral.

Example 1:

From Table 12.5A the friction loss for 1 gph on emitters spaced every 5 ft. on 10 mm hose is 1.5 psi for a 200 ft. row length. Since the allowable pressure variation within the zone is 1.5 psi, (10% of the 15 psi operating pressure) the header line would have to be designed with minimal friction loss in this case due to the 1.5 psi lateral line friction loss.

From Table 12.5F, the lateral line friction loss for 1.0 gph emitters spaced every 5 ft. on 15 mm hose is 0.25 psi for a 200 ft. row length.

The lateral size selected will depend upon any field slope that may occur as well as the header line design. A 15 mm hose may be recommended as it allows more flexibility in design.

Example 2:

The pressure loss through different sizes of tubing can be calculated by using Tables 12.10 - 12.16.
To use these tables the average flow per foot (AFPF) must be calculated.

$$\text{AFPF} = \frac{(\text{number of emitters/row}) \times (\text{emitter flow rate})}{\text{row length}}$$

For example 12.3.2, $\text{AFPF} = \frac{(40 \text{ emitters/row}) \times 1.0 \text{ gph/emitter}}{200 \text{ ft./row}}$

$= 0.2$ gph/ft.

From Table 12.10, for an AFPF of 0.2 gph/ft. and a row length of 200 ft., the friction loss in .520 I.D. tubing is 0.50 psi. An additional 30% friction loss is required to account for the emitter barbs in the line.

Total lateral friction loss = 0.50 psi + (30% of 0.50 psi)
= 0.65 psi total

Note: The allowable pressure loss due to elevation changes and friction loss in the header line is the total allowable loss in the zone minus the lateral friction loss (1.5 psi - 0.65 psi = 0.85 psi) - see section 12.5.

12.4.3 Line Source Lateral Selection

The flow characteristics for the line source lateral that has been selected are obtained from design charts provided by the manufacturer. Flow rates for line source laterals vary with lateral length and orifice spacing.

From example 12.3.3, the strawberry field was planted in a 1 ft. x 4 ft. spacing with row lengths of 400 ft. A 12 x 60 Bi-wall line source lateral was selected.

The maximum pressure variation in the line source lateral for a 10 psi zone inlet pressure is 0.5 psi. (This will allow for 0.5 psi loss in the header line for a total of 1.0 psi loss in the zone).

From table 12.6B, the maximum length of the Bi-wall on level ground is 200 ft. for an allowable loss of 0.5 psi along the lateral. For a row length of 400 ft., two 200 ft. laterals with a header bisecting the row is required.

Note: The maximum length of a line source lateral will vary with the slope of the land. Lateral lengths can be increased for land sloping downhill and must be decreased for land sloping uphill.

12.5 Header Line Design

The total pressure variation within a zone should not exceed $\pm$ 10% of the selected emitter operating pressure. The lateral line should be designed first and the friction loss calculated. The allowable header friction loss can then be obtained from:

The allowable friction loss in the header line = Total allowable pressure loss in zone - emitter (lateral) line friction loss $\pm$ elevation change.

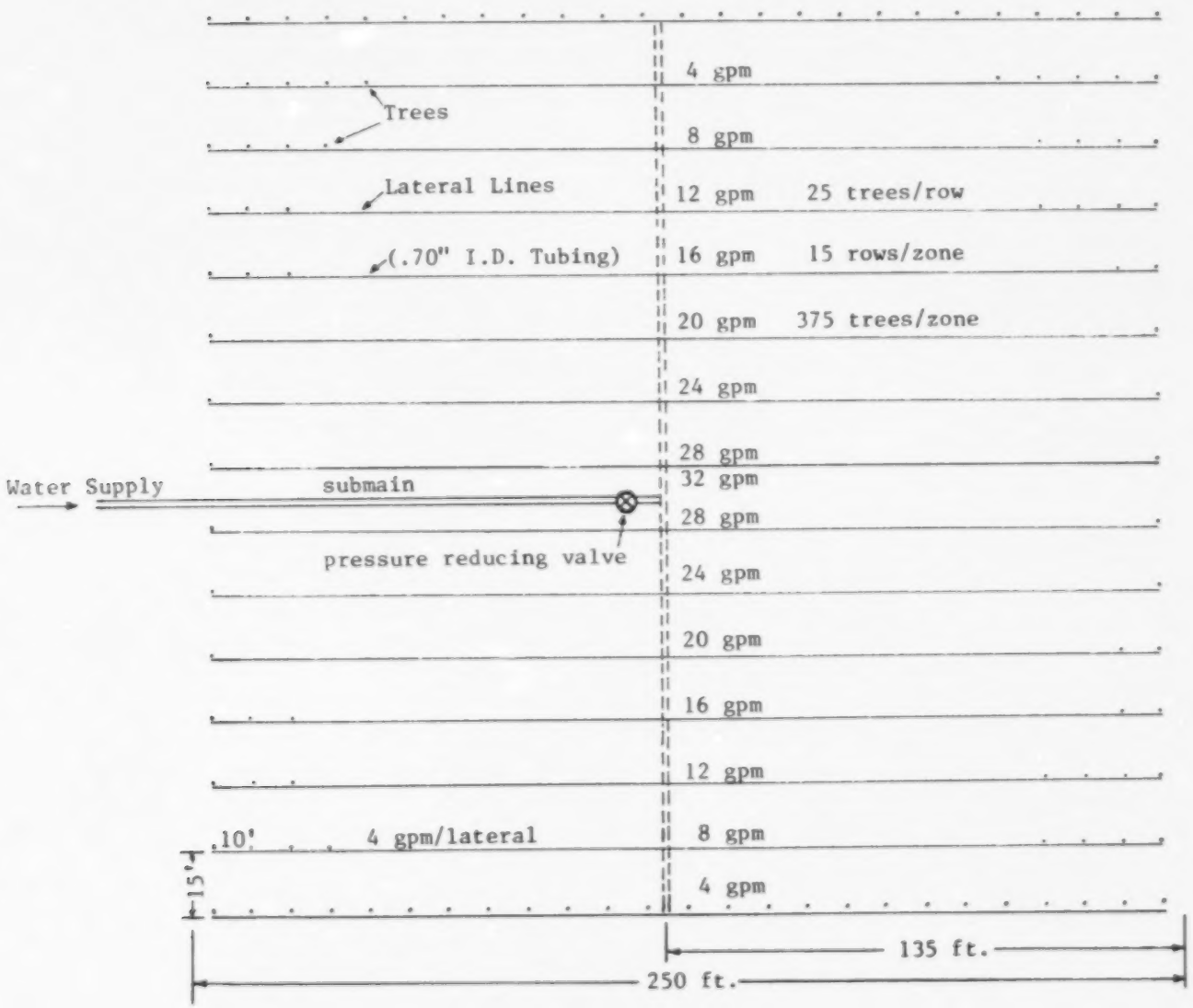
Any elevation difference that may exist must be accounted for in the design of the lateral line or header line. A trickle irrigation system should always be designed with the pressure reducing valve

at each zone located at the highest elevation in that zone. All pipelines will therefore either run level or downhill. If the land is sloping in the same direction as the lateral lines, the laterals must be sized to correct for elevation changes, or pressure compensating emitters must be used. If the land slopes in the same direction as the header lines, the header line must be sized to correct for these elevation changes.

12.5.1 Example of Header Design

An orchard with a 10 ft. x 15 ft. tree spacing is located in an area where the peak E.T. rate is 0.25 in./day. The 10 acre orchard has a total irrigation allotment of 60 gpm. Two 4.8 gph spray emitters operating at 15 psi are located at each tree.

The 10 acre orchard is broken into 8 identical zones of approximately 1.25 acres each. The layout of a zone is shown in the diagram.



From Section 12.3.1

The daily water requirement for a mature orchard crop on a 10' x 15' planting with a 0.25 in./day peak E.T. rate is

G/P/D = 0.623 x (0.25) x (0.75) x (150) x (0.90) = 15.8 gallons/plant/day

Plus 10% leaching = 1.6 G/P/D

Total = 17.4 G/P/D

Water supplied per row per hour = 25 trees/row x (2 x 4.8 gph/tree)

= 240 gph/row

= 4 gpm/row

Number of rows per zone = $\frac{60 \text{ gpm} \times 60 \text{ min./hr.}}{240 \text{ gph/row}}$

= 15 rows/zone

Gallons required per row per day = 17.4 G/P/D x 25 trees/row

= 435 gallons/row/day

Application time per zone = $\frac{435 \text{ gallons/row/day}}{240 \text{ gph/row}}$ = 1.8 hours/zone/day

= 1 hour 48 minutes/zone/day

From Section 12.4.1

The lateral line friction loss can be calculated using (AFPF)

AFPF = $\frac{50 \text{ emitters/row} \times 4.8 \text{ gph/emitter}}{250 \text{ ft. row length}}$ = 0.96 gph/ft.

Since the header line bisects the lateral line, the maximum length of the lateral is 125 ft. (See diagram).

From Table 12.12

The friction loss in 125 ft. of 0.70" poly tubing for a 0.96 gph/ft. flow rate is 0.45 psi.

Plus 30% additional loss due to emitter barbs = 0.14 psi

Total lateral loss = 0.59 psi

For an operating pressure of 15 psi the total loss within the zone should be limited to 1.5 psi. Assuming there is no elevation change throughout the zone, the allowable friction loss in the header line will be:

Total loss in the zone - total lateral friction loss =
1.5 psi - 0.59 psi = 0.91 psi

The header line friction loss is calculated as follows:
From Table 12.17

Section	Flow (gpm)	Length of Pipe	Pipe Size	Friction Loss (psi)
1	4 gpm	15 ft.	1 "	0.03 psi
2	8	15	1 "	0.13
3	12	15	1¼"	0.08
4	16	15	1¼"	0.14
5	20	15	1½"	0.11
6	24	15	1½"	0.15
7	28	15	2 "	0.07
8	32	7½	2 "	0.04

Total = 0.71 psi
Header line fitting loss (additional 20%) = 0.14 psi
Total header loss = 0.85 psi

For lateral spacings or flow rates other than those shown in Table 12.17, consult friction loss tables 13.4 - 13.11.

The total header loss of 0.85 psi does not exceed the maximum allowable loss of 0.91 psi.

If the entire header line is made up of 1½" PVC pipe the total friction loss in the header would be 0.67 psi. (From Table 12.17). The designer must therefore decide if the saving in reducing the pipe size is worthwhile. Quite often one size of pipe is used for a header design. This simplifies fittings required and makes installation easier.

TABLE 12.1 PEAK EVAPOTRANSPIRATION (ET) FOR TRICKLE IRRIGATION DESIGN

Location	ET (in/day)	Location	ET (in/day)
Abbotsford	.15	Kettle Valley	.27
Agassiz	.15	Kimberley	.30
Alexis Creek	.15	Ladner	.13
Armstrong	.21	Langley	.14
Ashcroft	.30	Lillooet	.28
Aspen Grove	.21	Lister	.21
Barriere	.20	Lumby	.23
Baynes Lake	.25	Lytton	.30
Campbell River	.20	Malakwa	.19
Canal Flat	.26	Merritt	.26
Castlegar	.31	Nanaimo	.19
Cawston	.32	Natal	.18
Chase	.21	Notch Hill	.20
Cherryville	.21	Oliver	.24
Chilliwack	.17	One Hundred Mile House	.23
Clinton	.23	Osoyoos	.28
Cloverdale	.14	Oyster River	.12
Comox	.20	Parksville	.16
Creston	.18	Pitt Meadows	.13
Donald	.14	Port Alberni	.20
Douglas Lake	.21	Prince George	.15
Duncan	.16	Princeton	.25
Ellison	.23	Quesnel	.26
Fort Fraser	.19	Radium	.20
Fort Steele	.22	Riske Creek	.28
Golden	.15	Saanichton	.16
Grand Forks	.19	Salmon Arm	.17
Grandview Flats	.25	Smithers	.15
Grasmere	.22	Spillimacheen	.19
Grinrod	.14	Sumas	.17
Hazelton	.19	Summerland	.26
Hixon	.16	Terrace	.30
Hope	.22	Vancouver	.18
Invermere	.23	Vanderhoof	.20
Joe Rich	.16	Vavenby	.16
Jura	.22	Vernon	.22
Kamloops	.28	Walhachin	.29
Kelowna	.24	Westwold	.27
Keremeos	.29	Williams Lake	.28
Kersley	.22		

TABLE 12.2 CROP COEFFICIENT FACTOR

PLANT	CROP COEFFICIENT	APPROPRIATE SPACINGS
Apples	0.90	8' x 16' to 20' x 20'
Apricots	0.80	
Cherries	0.90	
Peaches	0.80	
Pears	0.80	
Plums	0.80	
Grapes	0.70	5' x 12'
Blueberries	0.80	5' x 10'
Blackberries	0.50	8' x 10'
Logan berries	0.50	8' x 10'
Strawberries	0.75	2' x 4'
Raspberries	0.60	2½' x 10'
Tomatoes	0.90	1½' x 5'
Vegetables	0.75	1' x 3'

NOTE:

The crop coefficient factor accounts for the field area that is not utilized by the plants' canopy or root area. The crop coefficient factors listed are for mature crops and should only be used with plantings that closely approximate the plant spacings shown in the table. For larger plant spacings the crop coefficient factors may possibly be reduced.

A trickle irrigation system must be designed to supply the peak water requirements of the plant on a daily basis. The crop coefficient factor used must therefore reflect the requirements of a mature crop during the peak of the season. The operating time of the system can then be reduced to adjust for plant growth stages or seasonal E.T. changes that result in lower water requirements.

TABLE 12.3 LATERAL SPREAD OF WATER FROM POINT SOURCE EMITTERS

(From Guide to Design and Operation of Trickle Irrigation Systems - Dr. D.S. Stevenson)

Soil	Spread (Diameter in Feet)
Coarse soils, shallow, stony	5.0'
Fine soils, shallow, stony	5.0' - 6.0'
Loamy sand, deep	5.0'
Sandy loam, loam, deep	6.0' - 7.0'
Silt or silt loam, deep	6.0'

NOTE:

"At this time, the following are the maximum areas that can be expected to be irrigated with point source emitters and maintain relatively efficient irrigation; that is, without excessive losses of water to drainage, excessive water-logging, or conversely, gross under-irrigation of the crop.

a. Sand to loamy sand - 25 to 30 square feet per dripper.

b. Sandy loam to loam - 45 to 50 square feet per dripper.

c. Silt or silt loam - 35 to 40 square feet per dripper.

"No experience with clays or clay loam has been gained to date but presumably, these soils would behave somewhat like the silts. The reason that finer textured soils are assigned a smaller area than that for sandy loams is that while ultimately water will spread further in fine textured soils than in coarser textured ones, the rate of lateral transfer of water is too slow to accommodate the daily quantity of water required for larger areas. The result is severe water-logging over a large portion of each dripper area. This has been the experience in silt soils."

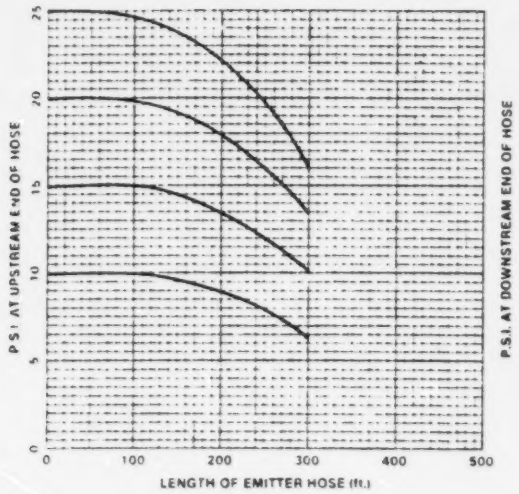
TABLE 12.4 SPRAY EMITTER SPECIFICATIONS

	Pressure (psi)	Discharge (gph)	40° Diameter (ft)	180° Radius (ft)	280° Diameter (ft)	360° 12 Hole Diameter (ft)	Orifice Velocity 20 psi (ft/sec)	Sq.ft 360°	Application Rate (in/hr) 360°
.03" Orifice Black Base	10	4.1	4.8	4.6	7.9	7.4	-	43	.15
	15	4.8	6.8	5.3	8.9	8.8	-	60	.13
	20	5.7	8.4	5.9	9.9	10.4	43.17	85	.11
	25	6.6	10.0	6.6	10.3	11.0	-	95	.11
.04" Orifice Blue Base	10	8.0	6.8	5.5	8.0	8.2	-	59	.24
	15	9.0	10.5	5.9	9.9	9.5	-	71	.20
	20	10.0	12.6	6.7	11.7	11.2	42.57	99	.16
	25	11.3	14.8	7.1	14.0	13.3	-	139	.13
.05" Orifice Green Base	10	10.5	7.9	6.1	10.2	11.0	-	95	.18
	15	13.0	11.6	6.6	11.5	12.6	-	125	.17
	20	14.8	15.7	8.1	12.3	14.5	40.34	165	.14
	25	16.5	17.6	8.5	13.0	16.2	-	206	.13
.06" Orifice Red Base	10	15.9	8.9	6.0	10.5	12.3	-	119	.22
	15	19.5	13.0	7.2	12.1	14.9	-	174	.18
	20	22.9	17.1	8.5	14.3	17.9	43.33	252	.15
	25	25.9	19.6	9.0	15.1	19.3	-	292	.14
.07" Orifice White Base	10	30.0	9.5	6.4	12.0	11.0	-	95	.50
	15	37.5	15.4	7.6	13.6	13.8	-	150	.40
	20	43.4	19.3	8.2	15.8	15.5	60.34	189	.37
	25	47.9	21.9	9.2	16.8	19.3	-	292	.27

TABLE 12.5 POINT SOURCE EMITTER LINE SPECIFICATIONS

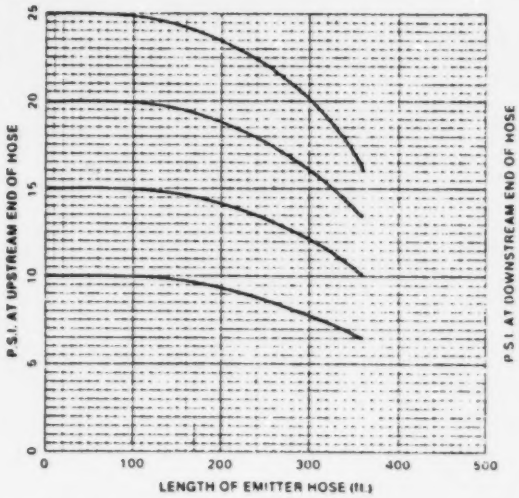
(Pressure Versus Length)

A



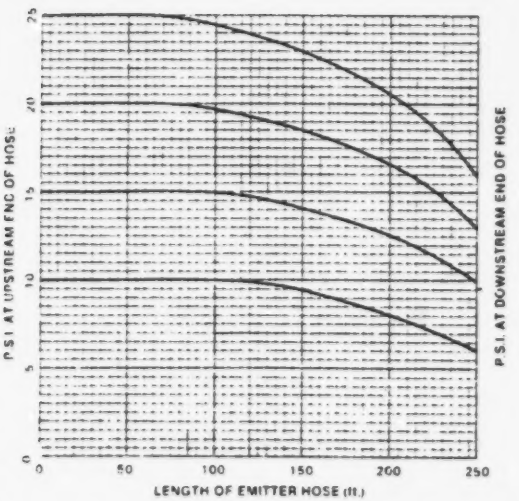
COMBINED PRESSURE LOSS
- 10mm Hose
- 1.0 GPH
- Snap-On Emitters
- 5' Spacing

B



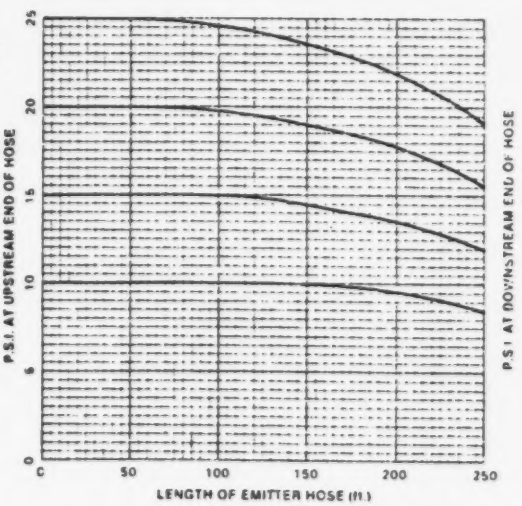
COMBINED PRESSURE LOSS
- 10mm Hose
- 1.0 GPH
- Snap-On Emitters
- 10' Spacing

C



COMBINED PRESSURE LOSS
- 10mm Hose
- 1.0 GPH
- Barbed Inline Emitters
- 5' Spacing

D

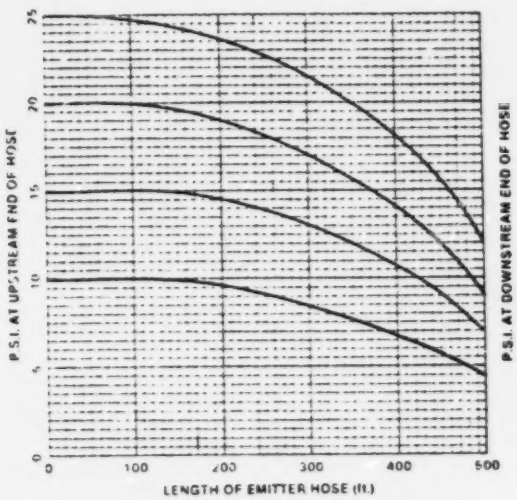


COMBINED PRESSURE LOSS
- 10mm Hose
- 1.0 GPH
- Barbed Inline Emitters
- 7' Spacing

TABLE 12.5 (Cont'd) POINT SOURCE EMITTER LINE SPECIFICATIONS

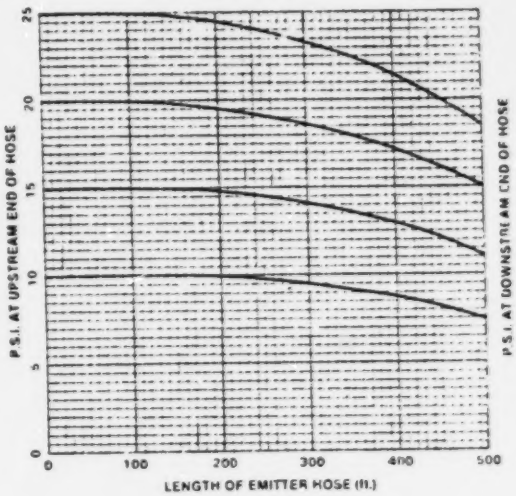
(Pressure Versus Length)

E



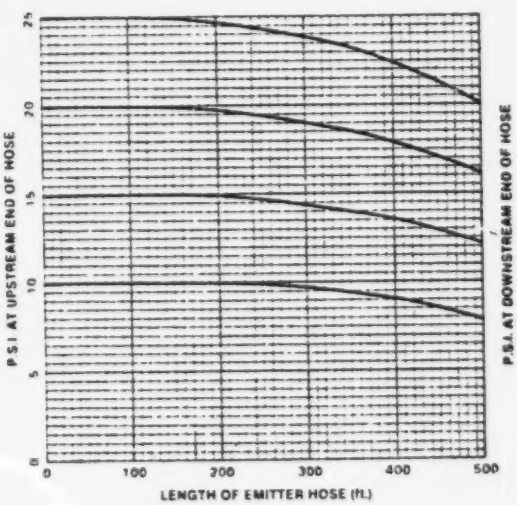
COMBINED PRESSURE LOSS
- 15mm Hose
- 1.0 GPH
- Barbed Inline Emitters
- 3' Spacing

F



COMBINED PRESSURE LOSS
- 15mm Hose
- 1.0 GPH
- Barbed Inline Emitters
- 5' Spacing

G

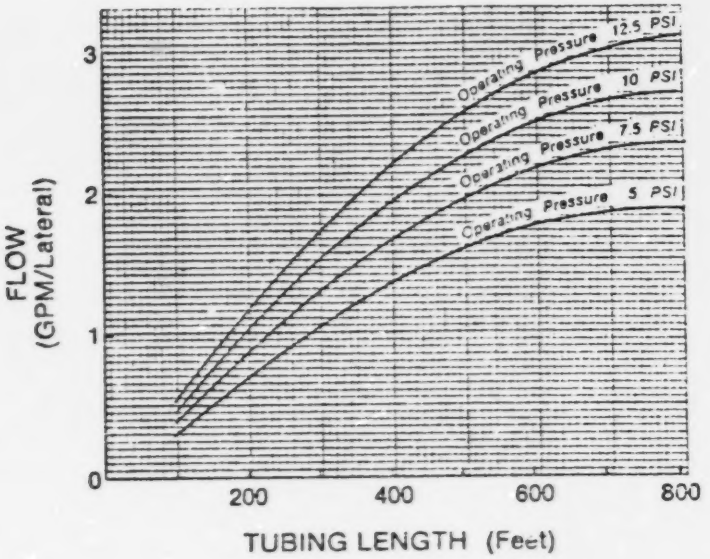


COMBINED PRESSURE LOSS
- 15mm Hose
- 1.0 GPH
- Barbed Inline Emitters
- 8' Spacing

TABLE 12.6 HYDRAULIC PERFORMANCE CHARTS BI-WALL 11 (12 x 60)

A

HYDRAULIC PERFORMANCE CHARTS
BI-WALL II
12 x 60 (30 cm x 150 cm)
Orifice Size .019 inches
0% Slope



B

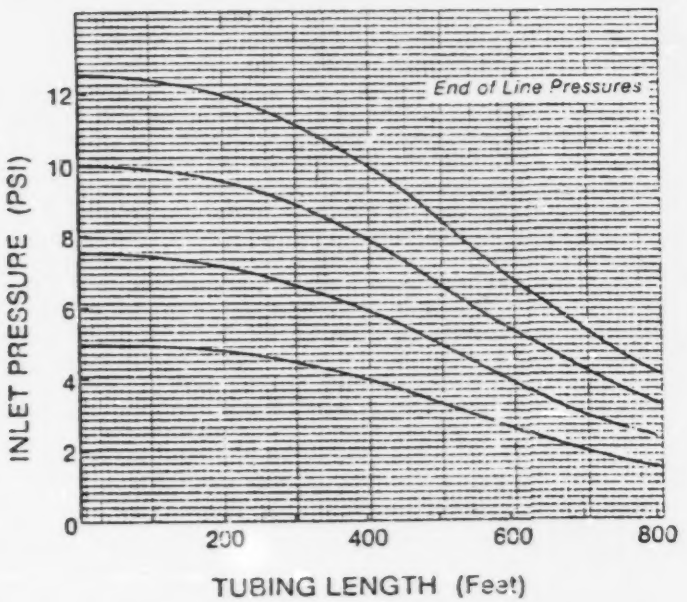
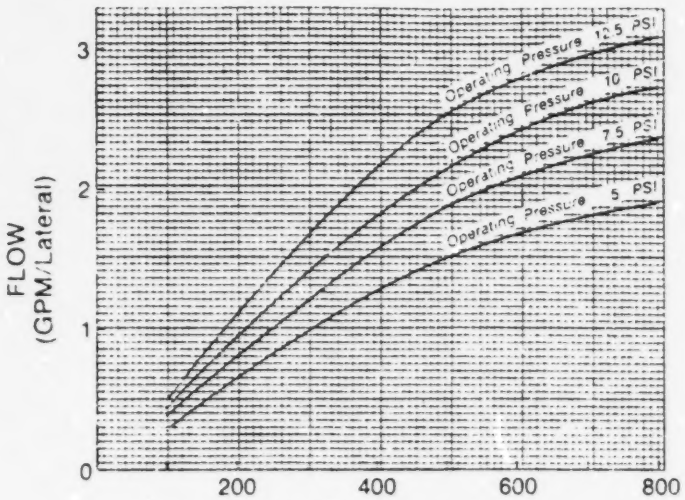


TABLE 12.7 HYDRAULIC PERFORMANCE CHARTS BI-WALL 11 (18 x 27)

A

HYDRAULIC PERFORMANCE CHARTS
BI-WALL II
18 x 72 (45 cm x 180 cm)
Orifice Size .019 inches
0% Slope



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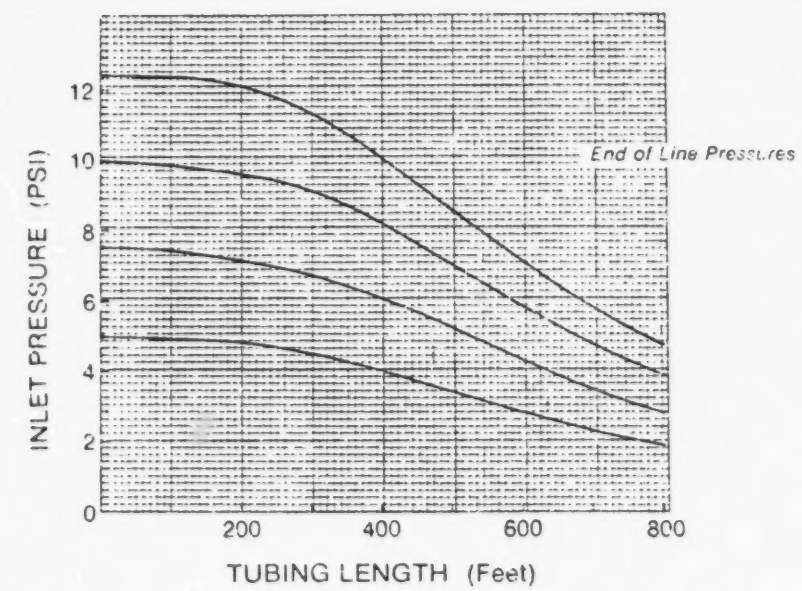
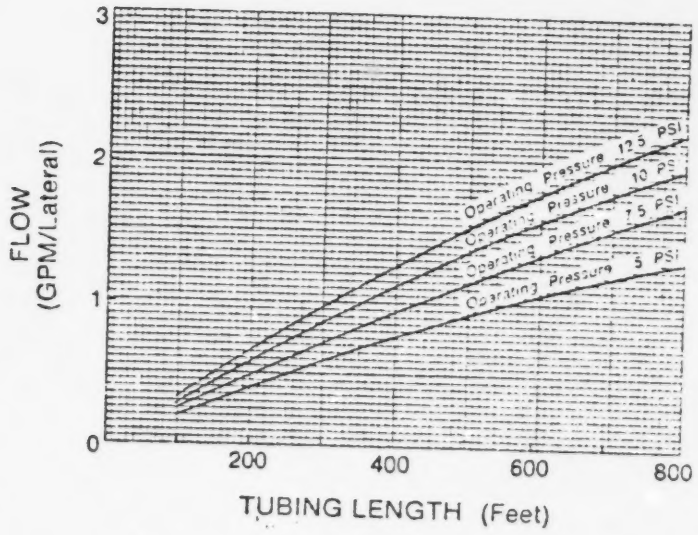


TABLE 12.8 HYDRAULIC PERFORMANCE CHARTS BI-WALL 11 (24 x 96)

A

HYDRAULIC PERFORMANCE CHARTS
BI-WALL II
24 x 96 (60 cm x 240 cm)
Orifice Size .019 inches
0% Slope



B

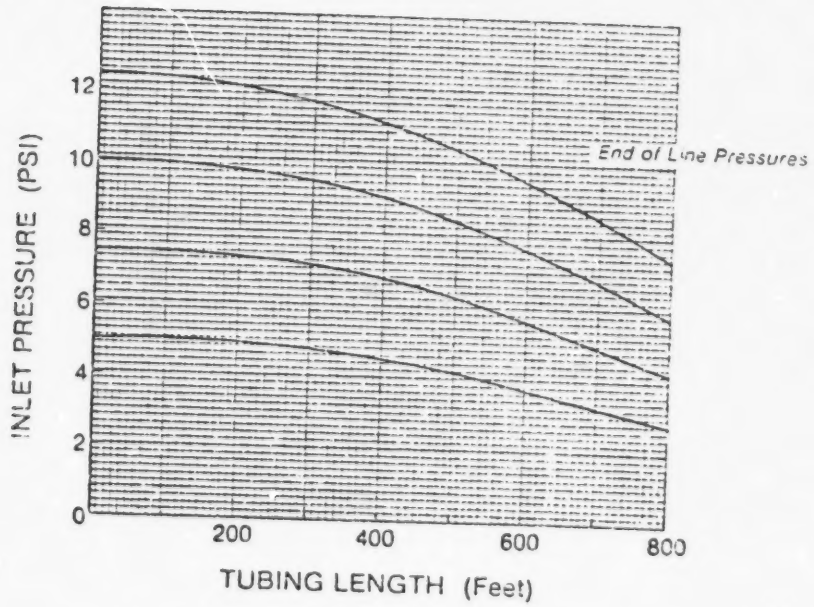
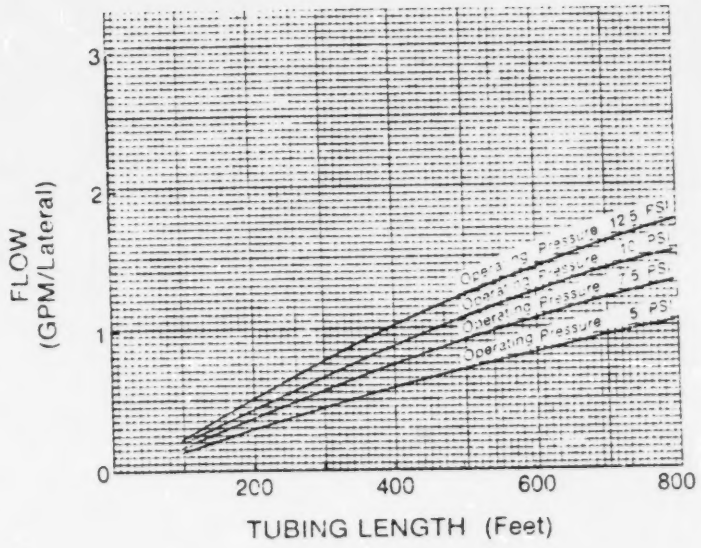


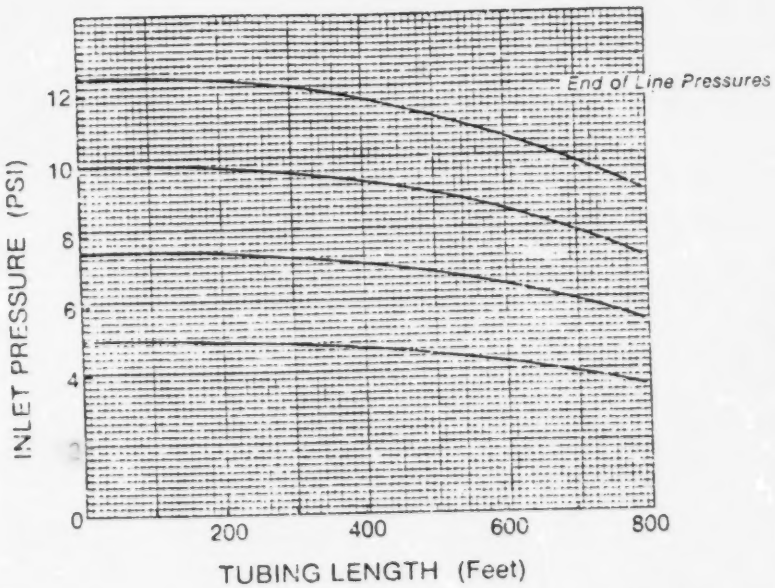
TABLE 12.9 HYDRAULIC PERFORMANCE CHARTS BI-WALL 11 (36 x 144)

A

HYDRAULIC PERFORMANCE CHARTS
BI-WALL II
36 x 144 (90 cm x 360 cm)
Orifice Size .019 inches
0% Slope



B



Pepco's Poly Plus Technical Bulletin has been prepared as a tool for designers of drip irrigation systems. The data will assist engineers in the selection of tubing sizes and provide the pressure loss for various lengths.

Variables which affect pressure loss include rate of flow, slope, the entrance effect of emitters, the number of emitters, diameter of tubing and temperature. Research scientists and engineers have been observing the effects of emitter discharge under various conditions. The studies included how these factors relate to the friction loss characteristics in drip irrigation distribution and lateral tubing. The number of variables and their range makes the task of pressure computation difficult and time consuming. Additionally, it has been shown that traditional irrigation industry methods of pressure loss computation can produce gross errors.

The curves and charts in this Technical Bulletin are a generalized graphic depiction of the results of Pepco's engineering studies of the phenomena.

LATERAL TUBING

Data is presented for Pepco Poly Plus 2 for the following sizes, inside diameters and Pepco part number:

1", 1.02 I.D. (P-1200); 3/4", 800 I.D. (P-940); 5/8", 700 I.D. (P-830); 1/2", 580 I.D. (P-704) and 16 mm, .520 I.D. (P-16)

Graphs 1 thru 5 provide the total pressure loss in a drip irrigation lateral line when its length, number of emitters and their flow rate are known (topography and emitter entrance effects are not considered in this presentation). It is necessary to make one computation prior to using this information. Calculate the average flow per foot (AFPF) by dividing the product of the number of emitters and their rate of flow by the length of lateral line.

Example: One hundred and twenty 2.2 gph emitters spaced along a 600 foot drip irrigation lateral line.

$$\frac{\text{(No. of emitters) x (emitter flow rate)}}{\text{length of drip lateral}} = \frac{120 \times 2.2}{600} = 44 \text{ AFPF}$$

By locating the AFPF curve closest to 44 it can be seen that the pressure loss in a 600 foot line is approximately 45 psi for .520 I.D. (P-16) tubing, 28 psi for .580 I.D. (P-704), 11 psi for .700 I.D. (P-830), 5.8 psi for .800 I.D. (P-940) and 1.6 psi for 1.02 I.D. (P-1200).

By following the above procedure a wide range of conditions can be quickly examined to assist in tube selection prior to engineering.

DISTRIBUTION TUBING

Graphs 6 and 7 are standard pressure/flow curves for all sizes of Pepco Poly Plus tubing. Table 1 gives the pressure loss per inch of length at flow rates from .5 gph to 10 gpm. Data is presented for Poly Plus tubing with diameters ranging from .040 in. to .375 in.

ENGLISH UNITS TO METRIC CONVERSION FACTORS
PSI/Ft. Multiply by .2296 for Kg/Cm²/M
GPM or GPH Multiply by 3.785 for LPM or LPH
Pounds per square inch Multiply by .07 for Kg/Cm²
Feet Multiply by .304 for Meters

TABLE 12.10

Pressure Loss vs Length For .520 I.D. Poly Plus P-16 Lateral Tubing

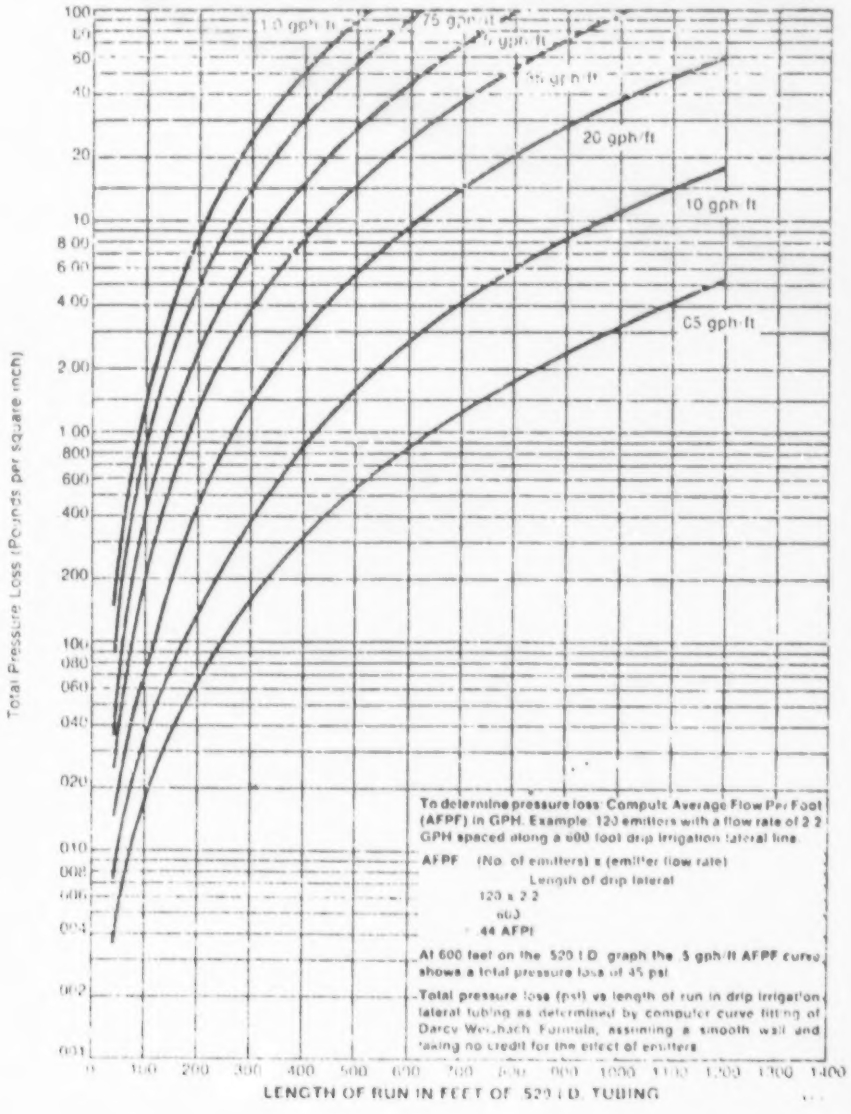


TABLE 12.11

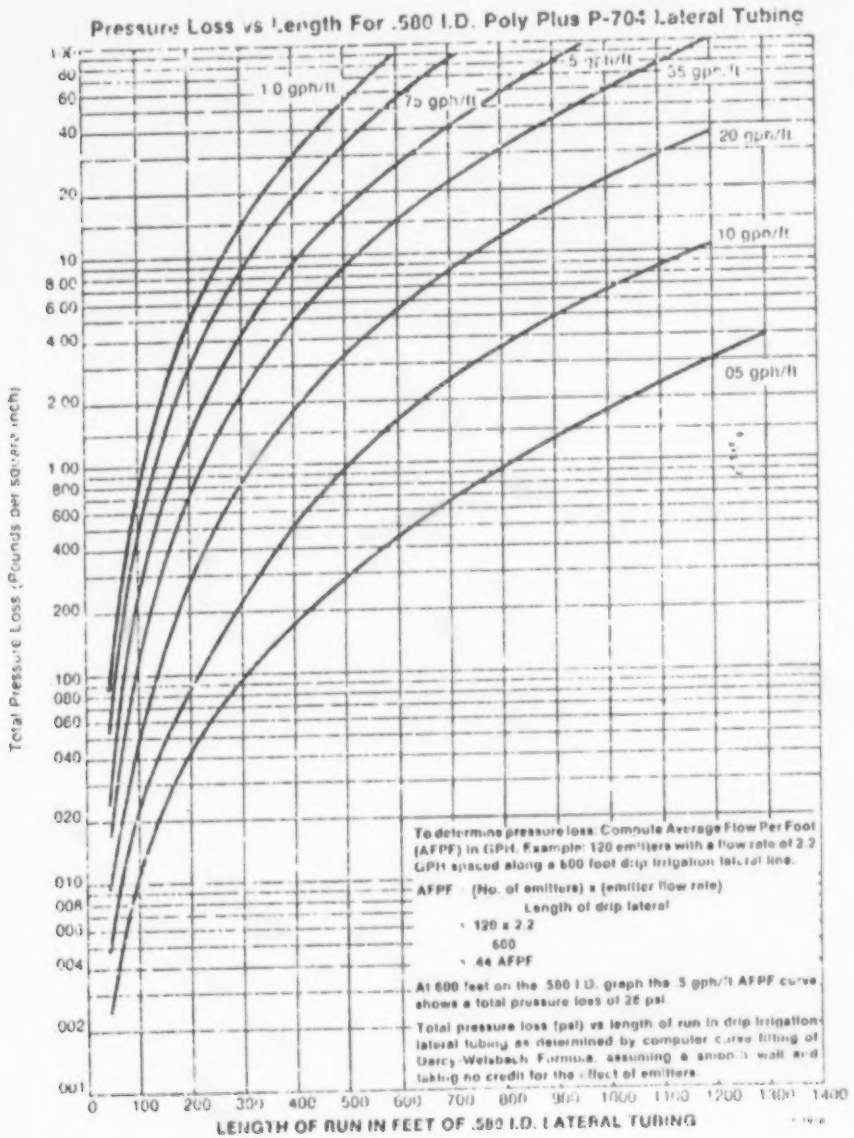

Pressure Loss vs Length For .500 I.D. Poly Plus P-704 Lateral Tubing
1.0 gph/ft
.75 gph/ft
.5 gph/ft
.35 gph/ft
.20 gph/ft
.10 gph/ft
.05 gph/ft
Total Pressure Loss (Pounds per square inch)
LENGTH OF RUN IN FEET OF .500 I.D. LATERAL TUBING
To determine pressure loss: Compute Average Flow Per Foot (AFPF) in GPH. Example: 120 emitters with a flow rate of 2.2 GPH spaced along a 600 foot drip irrigation lateral line.
AFPF = (No. of emitters) x (emitter flow rate) / Length of drip lateral
= 120 x 2.2 / 600
= .44 AFPF
At 600 feet on the .500 I.D. graph the .5 gph/ft AFPF curve shows a total pressure loss of 28 psi.
Total pressure loss (psi) vs length of run in drip irrigation lateral tubing as determined by computer curve fitting of Darcy-Weisbach Formula, assuming a smooth wall and taking no credit for the effect of emitters.

TABLE 12.12

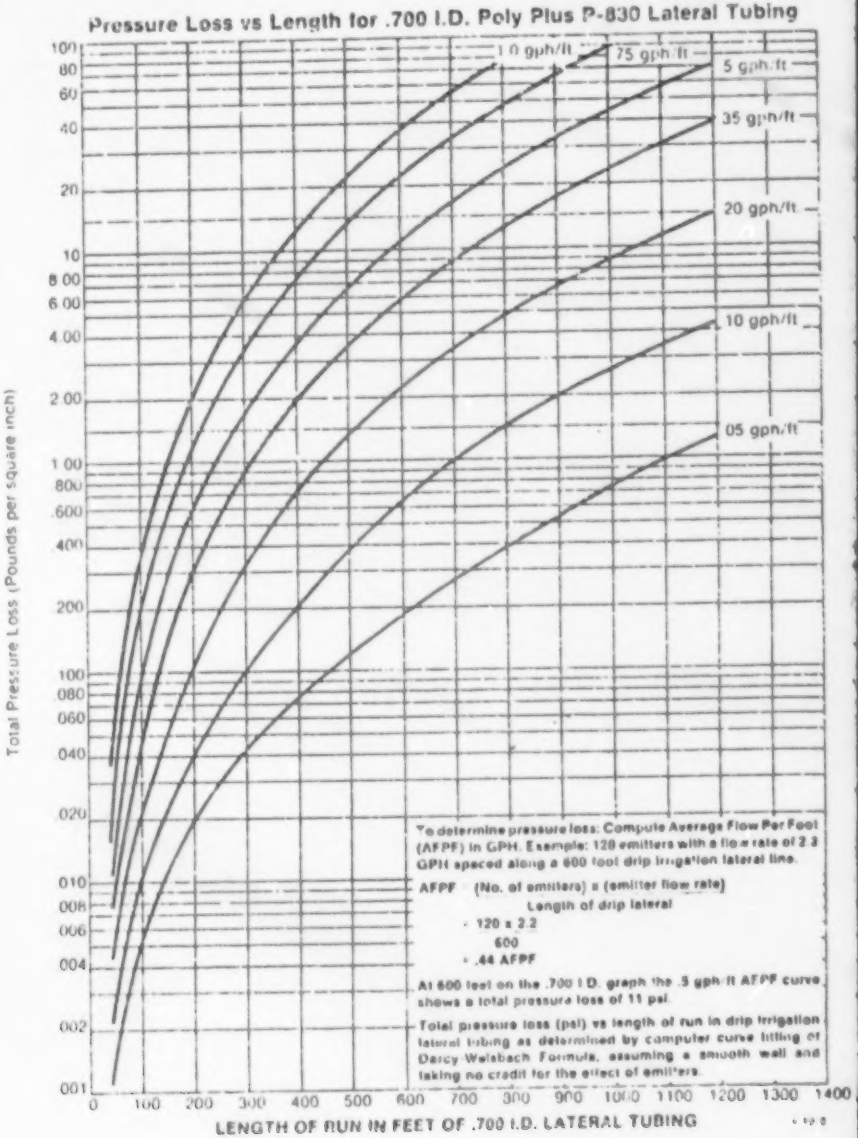

Pressure Loss vs Length for .700 I.D. Poly Plus P-830 Lateral Tubing
1.0 gph/ft
.75 gph/ft
.5 gph/ft
.35 gph/ft
.20 gph/ft
.10 gph/ft
.05 gph/ft
Total Pressure Loss (Pounds per square inch)
LENGTH OF RUN IN FEET OF .700 I.D. LATERAL TUBING
To determine pressure loss: Compute Average Flow Per Foot (AFPF) in GPH. Example: 120 emitters with a flow rate of 2.2 GPH spaced along a 600 foot drip irrigation lateral line.
AFPF = (No. of emitters) x (emitter flow rate) / Length of drip lateral
= 120 x 2.2 / 600
= .44 AFPF
At 600 feet on the .700 I.D. graph the .5 gph/ft AFPF curve shows a total pressure loss of 11 psi.
Total pressure loss (psi) vs length of run in drip irrigation lateral tubing as determined by computer curve fitting of Darcy Weisbach Formula, assuming a smooth wall and taking no credit for the effect of emitters.

TABLE 12.13

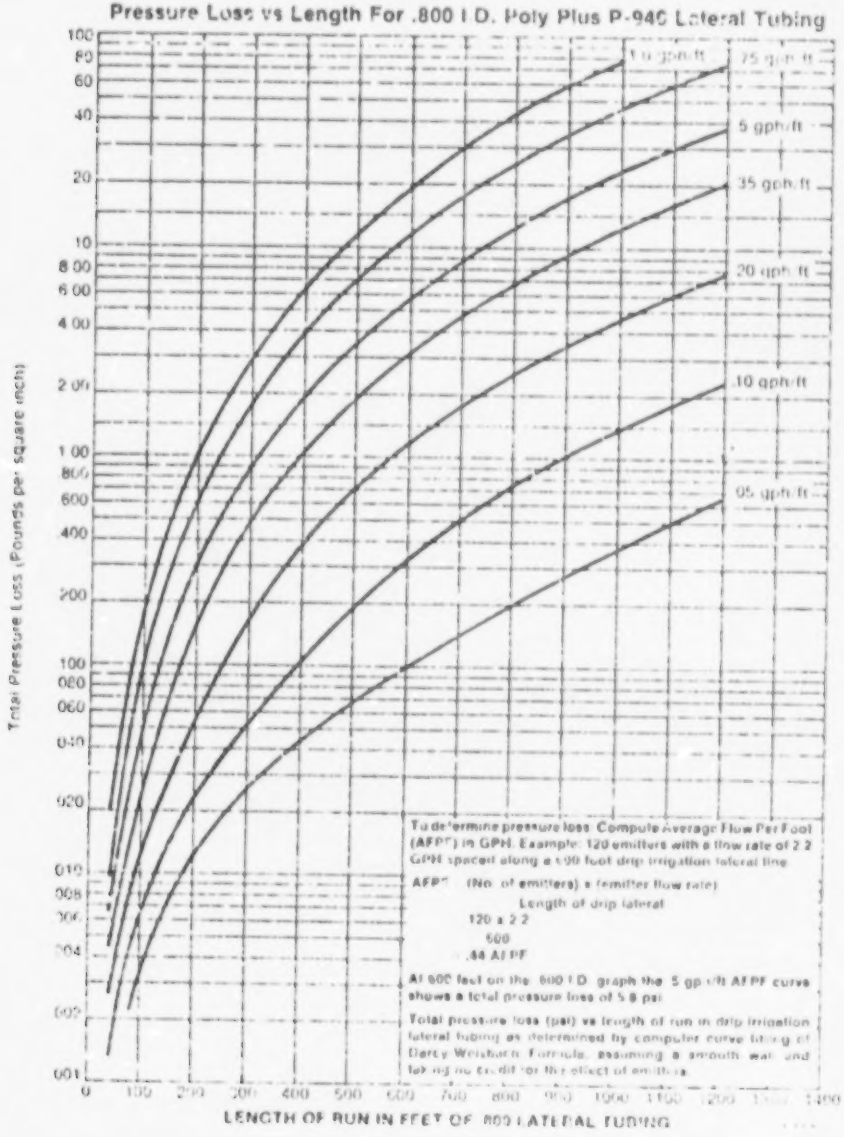
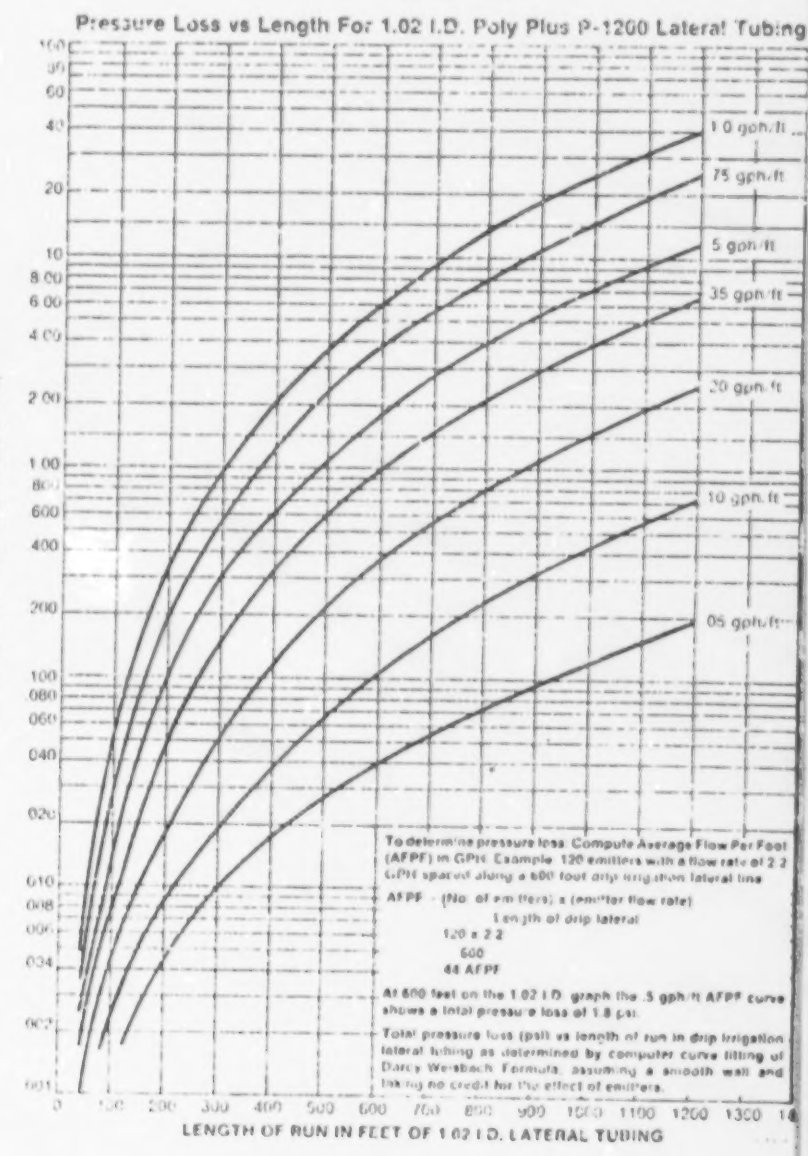

Pressure Loss vs Length For .800 I.D. Poly Plus P-940 Lateral Tubing
1.0 gph/ft
.75 gph/ft
.5 gph/ft
.35 gph/ft
.20 gph/ft
.10 gph/ft
.05 gph/ft
Total Pressure Loss (Pounds per square inch)
To determine pressure loss: Compute Average Flow Per Foot (AFPF) in GPH. Example: 120 emitters with a flow rate of 2.2 GPH spaced along a 600 foot drip irrigation lateral line
AFPF = (No. of emitters) x (emitter flow rate)
Length of drip lateral
120 x 2.2
600
= .44 AFPF
At 600 feet on the .800 I.D. graph the .5 gph/ft AFPF curve shows a total pressure loss of 5.8 psi.
Total pressure loss (psi) vs length of run in drip irrigation lateral tubing as determined by computer curve fitting of Darcy Weisbach Formula, assuming a smooth wall and taking no credit for the effect of emitters.
LENGTH OF RUN IN FEET OF .800 I.D. LATERAL TUBING

TABLE 12.14


Pressure Loss vs Length For 1.02 I.D. Poly Plus P-1200 Lateral Tubing
1.0 gph/ft
.75 gph/ft
.5 gph/ft
.35 gph/ft
.20 gph/ft
.10 gph/ft
.05 gph/ft
Total Pressure Loss (Pounds per square inch)
To determine pressure loss: Compute Average Flow Per Foot (AFPF) in GPH. Example: 120 emitters with a flow rate of 2.2 GPH spaced along a 600 foot drip irrigation lateral line
AFPF = (No. of emitters) x (emitter flow rate)
Length of drip lateral
120 x 2.2
600
= .44 AFPF
At 600 feet on the 1.02 I.D. graph the .5 gph/ft AFPF curve shows a total pressure loss of 1.8 psi.
Total pressure loss (psi) vs length of run in drip irrigation lateral tubing as determined by computer curve fitting of Darcy Weisbach Formula, assuming a smooth wall and taking no credit for the effect of emitters.
LENGTH OF RUN IN FEET OF 1.02 I.D. LATERAL TUBING

Pressure Loss Per 10 Feet Length of Pepco Poly Plus Tubing
.375 to 1.02 I.D. with flow rates from zero to 50 gpm.

TABLE 12.15

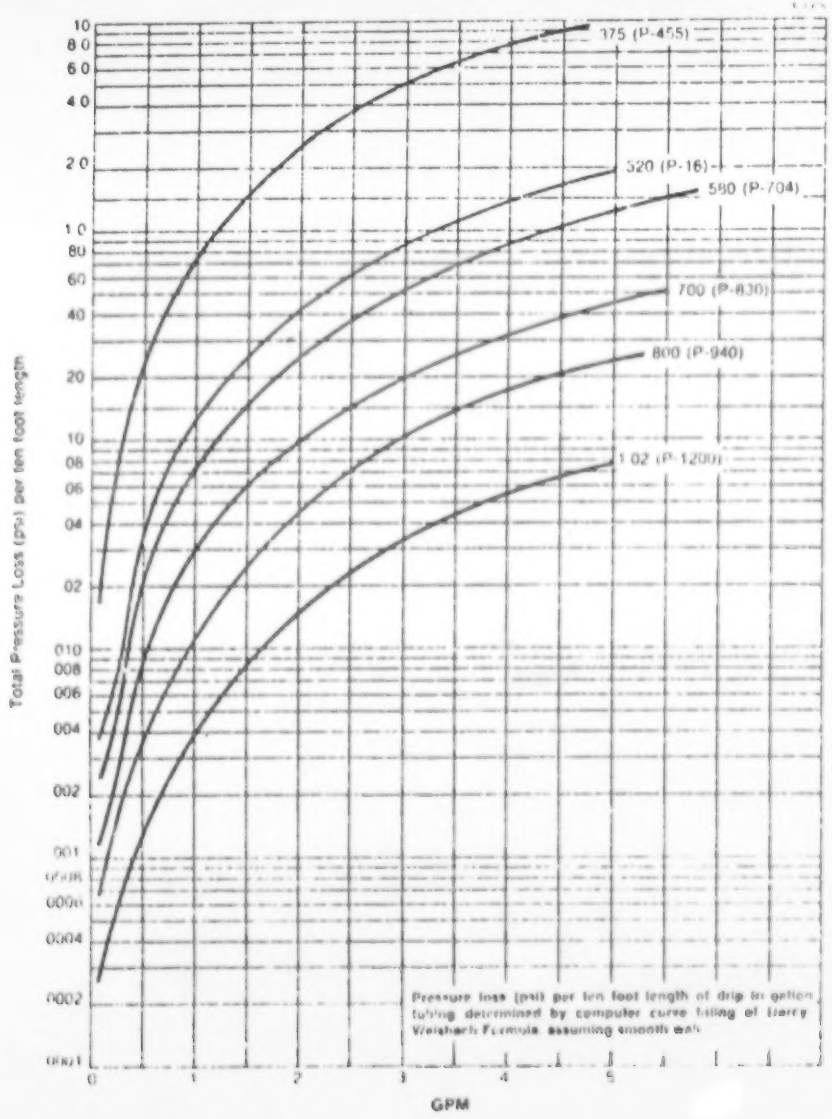

375 (P-455)
520 (P-16)
580 (P-704)
700 (P-830)
800 (P-940)
1.02 (P-1200)
Total Pressure Loss (psi) per ten foot length
GPM
Pressure loss (psi) per ten foot length of drip irrigation tubing determined by computer curve fitting of Darcy Weisbach Formula assuming smooth wall

TABLE 12.16

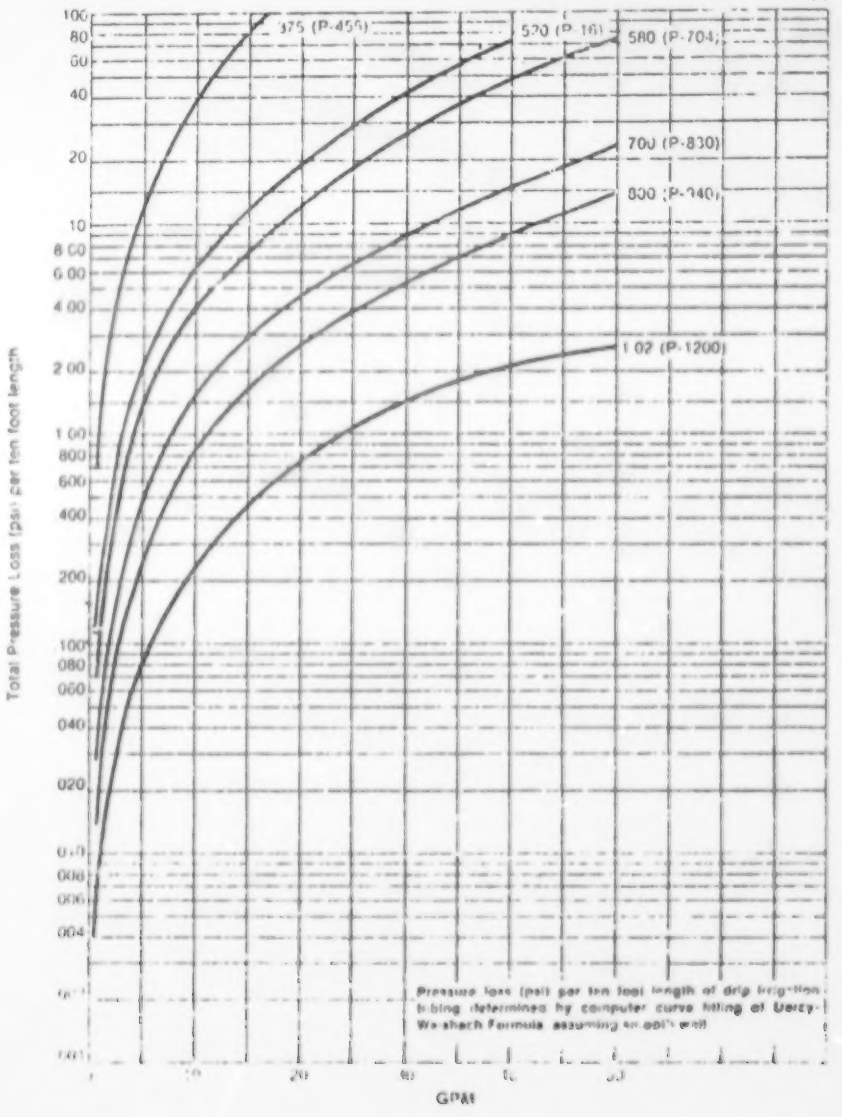

375 (P-455)
520 (P-16)
580 (P-704)
700 (P-830)
800 (P-940)
1.02 (P-1200)
Total Pressure Loss (psi) per ten foot length
GPM
Pressure loss (psi) per ten foot length of drip irrigation tubing determined by computer curve fitting of Darcy-Weisbach Formula assuming smooth wall

TABLE 12.17 HEADER FRICTION LOSS

(Loss in PSI for Class 160 PVC Pipe)

SIZE (in)	FLOW (gpm)	LENGTH OF LINE (ft.)							
		5	10	15	20	25	30	40	50
1 "	1	.001	.002	.003	.004	.005	.006	.008	.01
	2	.003	.006	.009	.012	.015	.018	.024	.03
	3	.01	.02	.02	.03	.04	.04	.06	.07
	4	.01	.02	.03	.05	.06	.07	.09	.12
	5	.02	.04	.05	.07	.09	.10	.14	.18
	6	.03	.05	.07	.10	.12	.15	.20	.25
	7	.03	.07	.10	.13	.17	.20	.26	.33
	8	.04	.08	.13	.17	.21	.25	.34	.42
	9	.05	.11	.16	.21	.26	.32	.42	.52
	10	.06	.13	.19	.25	.32	.38	.51	.64
	11	.08	.15	.23	.30	.38	.46	.61	.76
	12	.09	.18	.27	.36	.45	.53	.71	.89
	13	.10	.21	.31	.41	.52	.62	.83	1.04
1½"	10	.02	.04	.06	.08	.10	.12	.15	.19
	11	.02	.05	.07	.09	.11	.14	.18	.22
	12	.03	.05	.08	.11	.13	.16	.21	.27
	13	.03	.06	.09	.12	.16	.19	.25	.31
	14	.04	.07	.11	.14	.18	.21	.28	.36
	15	.04	.08	.12	.16	.20	.24	.32	.41
	16	.05	.09	.14	.18	.23	.27	.36	.45
	17	.05	.10	.15	.20	.26	.31	.41	.51
	18	.06	.11	.17	.23	.28	.34	.45	.57
	19	.06	.13	.19	.25	.31	.38	.50	.63
	20	.07	.14	.21	.27	.34	.41	.55	.69
	22	.08	.16	.25	.33	.41	.49	.66	.82
	24	.10	.19	.29	.38	.48	.58	.77	.96
	26	.11	.22	.33	.45	.56	.67	.89	1.12
	28	.13	.26	.38	.51	.64	.77	1.02	1.28
	30	.15	.29	.44	.58	.73	.87	1.16	1.46

SIZE	FLOW	LENGTH OF LINE (ft.)							
(in)	(gpm)	5	10	15	20	25	30	40	50
1½"	14	.02	.04	.06	.07	.09	.11	.15	.19
	16	.02	.05	.07	.09	.12	.14	.19	.24
	18	.03	.06	.09	.12	.15	.17	.23	.29
	20	.04	.07	.11	.14	.18	.21	.28	.36
	22	.04	.09	.13	.17	.21	.26	.34	.43
	24	.05	.10	.15	.20	.25	.30	.40	.50
	26	.06	.12	.17	.23	.29	.35	.46	.58
	28	.07	.13	.20	.26	.33	.40	.53	.66
	30	.08	.15	.23	.30	.38	.45	.60	.75
	32	.09	.17	.26	.34	.43	.51	.68	.85
	34	.10	.19	.29	.38	.48	.57	.76	.95
	36	.11	.21	.32	.42	.53	.63	.85	1.06
	38	.12	.24	.35	.46	.58	.70	.93	1.17
	40	.13	.26	.38	.51	.64	.77	1.02	1.28
	45	.16	.32	.48	.64	.80	.96	1.40	1.60
2 "	20	.01	.02	.04	.05	.06	.07	.10	.12
	22	.02	.03	.04	.06	.07	.09	.12	.15
	24	.02	.03	.05	.07	.09	.10	.14	.17
	26	.02	.04	.06	.08	.10	.12	.16	.20
	28	.02	.05	.07	.09	.11	.14	.18	.23
	30	.03	.05	.08	.10	.13	.15	.20	.26
	35	.03	.07	.10	.14	.17	.20	.27	.34
	40	.04	.09	.13	.17	.22	.26	.34	.43
	45	.05	.10	.16	.22	.27	.32	.43	.54
	50	.07	.13	.20	.26	.33	.39	.52	.66
	55	.08	.16	.23	.31	.39	.47	.62	.78
	60	.09	.18	.27	.37	.46	.55	.73	.92

12.6 Trickle Irrigation Water Treatment Requirements

The successful operation of a trickle irrigation system is dependent upon the quality of the water that is used. There are two water treatment methods which can be used in conjunction with a trickle irrigation system; chemical treatment and screening or filtration.

12.6.1 Chemical Treatment

(i) Chlorination

The addition of chlorine to the water supply may be required for Iron (Fe) or Sulphur (S) concentrations exceeding 0.5 ppm. The chlorination is required to prevent the buildup of algae growth, which is very predominant in the presence of Fe or S.

A suggested maximum concentration of chlorine is 40 ppm. Concentrations exceeding 40 ppm may cause chemical precipitates to form.

A formula that can be used to calculate the injection rate of a chlorine solution is:

$$GPH_{BLEACH} = Q \times \frac{\text{Desired Cl Concentration}}{1{,}000{,}000} \times 60 \times \frac{100}{\text{\% Cl concentration of bleach}}$$

Q = Trickle system flow rate in gallons per minute

GPH_{BLEACH} = Gallons per hour of solution to be added to the water supply.

Desired Cl concentration = Desired residual chlorine concentration (ppm) of water supply.

% Cl concentration of bleach = Chlorine concentration of solution to be added (%)

Example:

Calculate the GPH of solution required to inject 30 ppm into a system flow rate of 60 gpm using a 12% Sodium Hypochlorite solution. (Bleach)

Q = 60 gpm

Desired Cl concentration = 30 ppm

% Cl concentration of bleach = 12%

$$GPH_{BLEACH} = 60 \text{ gpm} \times \frac{30 \text{ ppm}}{1{,}000{,}000} \times 60 \times \frac{100}{12} = 0.9 \text{ GPH of solution}$$

If we wish to inject for 4 hours, a 4 gallon container would be required.

(ii) Acid Treatment

The addition of acid may be required for water containing concentrations of Ca or Mg greater than 50 ppm, due to the formation of Calcium Carbonate ($CaCO_3$) or magnesium carbonate ($MgCO_3$) precipitates. Professional advice should be obtained before attempting to inject an acid for pH control.

Additional information on chemical treatment requirements for trickle irrigation systems can be obtained from the Engineering Branch, B.C. Ministry of Agriculture & Food.

12.6.2 Filtration Requirements

The selection of a trickle irrigation filtration system is dependent on the following:

1. The size, nature and concentration of the contaminant in the water supply.
2. The filtration requirements of the trickle system. (i.e. emitter orifice size).
3. The flow rate of the trickle system.
4. The capital expenditure of the filtration package.

The filtration system must be capable of removing all particles larger than 1/6th of the emitter orifice diameter out of the water supply.

A screen mesh filter should be used in situations where the particulate in the water is predominantly inorganic and of a relatively low concentration (10 mg/l or less).
Automatic backflush screen filters can be used if the screen plugs up quite quickly on a continuous basis. Table 12.18 gives the filtration capabilities of different screen mesh sizes.

Table 12.18 Equivalent Micron Filtration For a Given Screen Mesh Size

Screen Mesh	Filtration to Micron Size
80	175
100	147
150	104
200	74

Note: 0.001 inches is equal to 25 microns

From Table 12.18, a 100 mesh screen will filter everything larger than 150 microns out of the water supply.

A sand media filter should be used instead of screen filters whenever the water contains a high concentration of organic particulates. A sand filter has the capability of retaining a large volume of suspended solids while continuing to deliver the rated flow of filtered water. Sand filters should always be operated in dual units so that clean water from one unit can be used to backflush the other.

Table 12.19 shows a comparison of the sand media filtrative capacity versus an equivalent screen mesh. Due to a slight variation that can occur in the size of sand particles, the sand designation is given a range of an equivalent screen mesh.

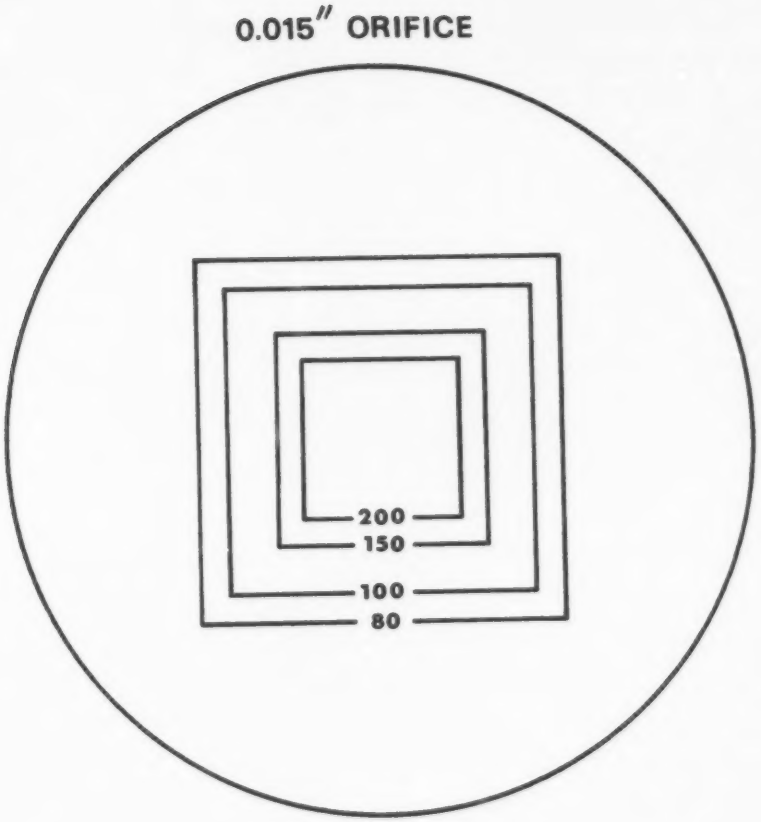
Table 12.19 Comparison of Sand Media Filters & Screen Mesh Equivalent

Sand Designation No.	Screen Mesh Equivalent
# 8 Crushed Granite	70 - 140
# 11 Crushed Granite	140 - 200
# 16 Silica Sand	140 - 200
# 20 Silica Sand	200 - 230

All sand media filters should have a stainless steel or nylon backup screen. This protects the trickle system in the event of the sand filter malfunctioning.

Additional information on water quality for the Okanagan-Similkameen is available from the Engineering Branch, B.C. Ministry of Agriculture and Food.

Table 12.20 - COMPARISON OF A 0.015-INCH ORIFICE TO OPENINGS OF AN 80, 100, 150 AND 200 MESH SCREEN



80 MESH - (175 Microns)
100 MESH - (147 Microns)
150 MESH - (104 Microns)
200 MESH - (74 Microns)

Courtesy of Ronald Below
1976

12.7 Suggested Trickle Irrigation System Components

The following list of components are suggested for maximum performance and monitoring of a trickle irrigation system. The components are listed in order from the water source to the emitter.

(See plan 565.005 for sketch of components).

1. Main shut-off valve.
2. Preliminary coarse screen. (This could be a well screen or irrigation district screen).
3. BACKFLOW PREVENTER.
4. Take-off for filling sprayer.
5. Live hose bib for cleaning screens.
6. Pressure gauge.
7. Secondary shut-off valve.
8. Chlorine injector (can also be used as a fertilizer injector).
9. Pressure gauge.
10. Sand filters or screen.
11. PRESSURE RELIEF VALVE - when filters and screen require high pressure protection.
12. Throttle valve on backflush discharge line and access to backflush water.
13. Pressure gauge.
14. Back-up screen (See Section 12.6.2).
15. Drain for filters and screens.
16. Pressure gauge.
17. Shut-off valve to emitter system.
18. VACUUM BREAKER - to emitter system.
19. Air blow-out connection: - for winterizing system.
    - use copper or other non-ferrous metal due to the heat produced.
20. Supply line to emitter zones.
21. Shut-off valve at header line.
22. Pressure reducing valve at header line at each zone.
23. Pressure gauge at beginning of header line.
24. Header line complete with end flushing and draining ability.
25. Emitter line complete with risers, emitters, tubing etc., complete with end flushing and draining ability.

Automation is easily achieved by installation of the necessary time clocks, wiring and solenoid valves.

PART XIII – FRICTION LOSS IN IRRIGATION PIPE

Water flowing in pipes is always accompanied by a loss of pressure due to friction. The amount of friction loss depends upon:

a). dimensions of the pipe (length, inside diameter (ID) or
b). outside diameter (OD))
c). type of pipe (aluminum, PVC, steel, etc.)
quantity of water flowing through the pipe.

Velocities in pipes should be less than 5 feet per second. All values below the dark lines in the friction loss tables are in excess of 5 feet per second and should therefore be avoided. Some pressure ratings for various pipes are included as auxilliary information.

TABLE 13.1 BURST AND WORKING PRESSURES OF ALUMINUM IRRIGATION TUBING

Tube Size (inches)	Wall Thickness (inches)	Bursting Pressures (psi)	Maximum Recommended Working Pressure (psi)*
2	.050	1380	460
3	.050	766	255
4	.050	660	220
4	.072	1050	350
5	.052	555	185
5	.078	717	239
6	.058	450	150
6	.083	636	212
7	.064	393	131
8	.051	300	100
8	.064	375	125
8	.072	441	147
10	.051	255	85
10	.064	330	110
10	.072	351	117
10	.094	459	153
12	.064	270	90

*Based on 3 to 1 safety factor

$$P=\frac{2st}{d}$$

P = Bursting Pressure (psi)
s = Stress (23,000 psi)
t = Wall thickness (in)
d = Tubing Diameter(in)

TABLE 13.2 FRICTION LOSS - ALUMINUM TUBING

Pressure Loss from Friction in psi per 100 feet of Pipe

Flow (gpm)	2"O D	3"O D	4"O D	5"O D	6"O D	7"O D	8"O D	10"O D
5	.03							
10	.14	.02						
15	.31	.04						
20	.52	.07	.02					
25	.79	.10	.03					
30	1.12	.14	.03					
40	1.95	.24	.06	.02				
50	2.97	.37	.09	.03	.01			
60	4.19	.52	.12	.04	.02			
70	5.61	.70	.16	.05	.02			
80	7.23	.89	.21	.07	.03	.01		
90	9.01	1.12	.26	.09	.03	.02		
100	11.00	1.38	.32	.10	.04	.02	.01	
110		1.64	.38	.12	.05	.03	.01	
120		1.95	.46	.15	.06	.03	.02	
130		2.24	.53	.17	.07	.04	.02	
140		2.60	.61	.20	.08	.04	.02	
160		3.36	.79	.26	.10	.05	.03	
180		4.19	.98	.32	.13	.06	.03	
200		5.12	1.20	.39	.16	.07	.04	
220		6.11	1.43	.46	.19	.09	.05	
240		7.24	1.69	.55	.23	.10	.06	.02
260		8.41	1.97	.64	.26	.12	.06	.02
280		9.70	2.28	.74	.30	.14	.07	.03
300		11.02	2.59	.84	.34	.16	.08	.03
350			3.48	1.12	.46	.22	.11	.04
400			4.49	1.44	.59	.28	.14	.05
450			5.59	1.80	.73	.35	.18	.06
500			6.81	2.20	.89	.42	.22	.08
550			8.28	2.67	1.08	.51	.27	.09
600			9.73	3.14	1.27	.60	.31	.11
650			11.30	3.65	1.48	.70	.36	.13
700				4.19	1.70	.81	.42	.14
750				4.79	1.93	.91	.48	.16
800				5.40	2.18	1.03	.54	.19
850				6.04	2.44	1.16	.60	.21
900				6.78	2.75	1.29	.68	.23
950				7.51	3.04	1.44	.75	.26
1000				8.27	3.44	1.58	.82	.28
1100				9.90	3.99	1.89	.98	.32
1200				11.67	4.71	2.23	1.16	.39
1300					5.47	2.58	1.34	.43
1400					6.43	2.99	1.56	.51
1500					7.22	3.41	1.76	.60
1600					8.14	3.85	2.00	.70
1700					9.07	4.31	2.23	.78
1800					10.22	4.83	2.51	.86
1900						5.35	2.78	.95
2000						5.91	3.07	1.05

Based on Scobey's Formula / KS = 34 for 2" Pipe KS = 32 for other sizes.

NOTE: This chart shows losses without couplers because of variation in pipe lengths and in losses through various types of couplers. If specific loss figures are not available for type used, add equivalent loss of 6' of pipe per coupler to obtain available loss figure for pipe with couplers.

TABLE 13.3 TEST AND WORKING PRESSURES OF STRAIGHT SEAM STEEL PIPE

O D (Inches)	Wall Thickness		Test Pressure (psi) (75% of 42,000 Yield)	Working Pressure (psi)
	Decimal	Gage or Fraction		
4	.060	16	945	630
4	.075	14	1181	787
4	.105	12	1653	1102
4	.134	10	2110	1407
5	.075	14	945	630
5	.105	12	1323	882
5	.134	10	1688	1125
5	.188	3/16"	2368	1579
6	.075	14	787	525
6	.105	12	1102	735
6	.134	10	1407	938
6	.188	3/16"	1974	1316
8	.075	14	590	393
8	.105	12	826	551
8	.134	10	1055	703
8	.188	3/16"	1480	987
10	.105	12	661	441
10	.134	10	844	562
10	.188	3/16"	1184	789
10	.250	1/4"	1575	1050
12	.105	12	551	367
12	.134	10	703	469
12	.188	3/16"	987	658
12	.250	1/4"	1312	875
14	.105	12	472	315
14	.134	10	603	402
14	.188	3/16"	846	564
14	.250	1/4"	1125	750
14	.312	5/16"	1404	936
16	.105	12	413	275
16	.134	10	527	351
16	.188	3/16"	740	493
16	.250	1/4"	984	656
16	.312	5/16"	1228	819

TABLE 13.4 FRICTION LOSS - AGED STEEL PIPE, 14 GAUGE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Outside Diameter Pipe Size							
	4"	5"	6"	8"	10"	12"	14"	16"
40	.06	.01						
50	.09	.01						
60	.12	.03						
70	.16	.04						
80	.23	.07	.03					
90	.27	.09	.03					
100	.32	.11	.04					
125	.52	.16	.06					
150	.71	.23	.09					
175	.97	.31	.13	.03				
200	1.22	.40	.16	.04				
250	1.93	.61	.25	.06	.02			
300	2.71	.87	.35	.08	.03			
350	3.62	1.16	.46	.11	.03	.01		
400	4.63	1.49	.60	.14	.05	.02		
450	5.89	1.87	.74	.18	.06	.02		
500	7.19	2.28	.91	.22	.07	.03	.01	
600		3.23	1.30	.31	.10	.04	.02	
700		4.33	1.74	.41	.13	.06	.03	.01
800		5.59	2.23	.53	.17	.07	.03	.02
900			2.80	.67	.22	.09	.04	.02
1000			3.43	.81	.27	.11	.05	.03
1200			4.81	1.17	.38	.15	.07	.03
1400				1.53	.50	.20	.10	.05
1600				1.97	.65	.26	.12	.06
1800				2.47	.81	.33	.15	.08
2000				3.03	1.01	.39	.19	.10
2500				4.63	1.53	.61	.29	.15
3000					2.13	.86	.40	.21
3500					2.88	1.16	.54	.28
4000					3.70	1.50	.70	.36
4500						1.86	.87	.45
5000						2.29	1.07	.55
6000						3.23	1.51	.78
7000							2.02	1.04
8000							2.60	1.34
9000								1.68
10,000								2.05

NOTE: Based on C = 100

TABLE 13.5 FRICTION LOSS - SCHEDULE 40 STANDARD STEEL PIPE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size							
	4"	5"	6"	8"	10"	12"	14"	16"
40	0.10	0.03	0.01					
50	0.14	0.05	0.02					
60	0.20	0.07	0.03					
70	0.27	0.09	0.04					
80	0.34	0.11	0.05	0.01				
90	0.43	0.14	0.06	0.02				
100	0.52	0.17	0.07	0.02				
120	0.73	0.24	0.10	0.03				
140	0.97	0.32	0.13	0.03	0.01			
160	1.24	0.41	0.17	0.04	0.01			
180	1.55	0.51	0.21	0.06	0.02		0.00	
200	1.88	0.63	0.26	0.07	0.02	0.01	0.01	
250	2.84	0.95	0.39	0.10	0.03	0.01	0.01	
300	3.98	1.33	0.54	0.14	0.05	0.02	0.01	
350	5.30	1.76	0.72	0.19	0.06	0.03	0.02	
400	6.78	2.26	0.92	0.24	0.08	0.03	0.02	0.01
450	8.43	2.81	1.15	0.30	0.10	0.04	0.03	0.01
500	10.25	3.41	1.40	0.37	0.12	0.05	0.03	0.02
550		4.07	1.67	0.44	0.14	0.06	0.04	0.02
600		4.78	1.96	0.51	0.17	0.07	0.05	0.02
650		5.55	2.27	0.60	0.20	0.08	0.05	0.03
700		6.36	2.60	0.68	0.23	0.10	0.06	0.03
750		7.23	2.96	0.78	0.26	0.11	0.07	0.04
800		8.15	3.33	0.88	0.29	0.12	0.08	0.04
850			3.73	0.98	0.32	0.14	0.09	0.05
900			4.15	1.09	0.36	0.15	0.10	0.05
950			4.58	1.21	0.40	0.17	0.11	0.06
1000			5.04	1.33	0.44	0.19	0.12	0.06
1100			6.01	1.58	0.52	0.22	0.14	0.07
1200			7.06	1.86	0.61	0.26	0.17	0.09
1300				2.15	0.71	0.30	0.19	0.10
1400				2.47	0.82	0.35	0.22	0.11
1500				2.81	0.93	0.40	0.25	0.13
1600				3.16	1.05	0.45	0.28	0.15
1700				3.54	1.17	0.50	0.31	0.16
1800				3.94	1.30	0.55	0.35	0.18
1900				4.35	1.44	0.61	0.39	0.20
2000				4.78	1.58	0.67	0.43	0.22
2500					2.39	1.02	0.64	0.34
3000					3.35	1.43	0.90	0.47
3500						1.90	1.20	0.63
4000						2.43	1.53	0.80
4500						3.03	1.91	1.00
5000						3.68	2.32	1.21

NOTE: Based on C = 100

TABLE 13.6 FRICTION LOSS - POLYETHYLENE (PE) SDR-PRESSURE RATED PIPE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size							
	½"	3/4"	1"	1¼"	1½"	2"	2½"	3"
1	0.49	0.12	0.04	0.01				
2	1.76	0.45	0.14	0.04	0.02			
3	3.73	0.95	0.29	0.08	0.04	0.01		
4	6.35	1.62	0.50	0.13	0.06	0.02		
5	9.60	2.44	0.76	0.20	0.09	0.03		
6	13.46	3.43	1.06	0.28	0.13	0.04	0.02	
7	17.91	4.56	1.41	0.37	0.18	0.05	0.02	
8	22.93	5.84	1.80	0.47	0.22	0.07	0.03	
9		7.26	2.24	0.59	0.28	0.08	0.03	
10		8.82	2.73	0.72	0.34	0.10	0.04	0.01
12		12.37	3.82	1.01	0.48	0.14	0.06	0.02
14		16.46	5.08	1.34	0.63	0.19	0.08	0.03
16			6.51	1.71	0.81	0.24	0.10	0.04
18			8.10	2.13	1.01	0.30	0.13	0.04
20			9.84	2.59	1.22	0.36	0.15	0.05
22			11.74	3.09	1.46	0.43	0.18	0.06
24			13.79	3.63	1.72	0.51	0.21	0.07
26			16.00	4.21	1.99	0.59	0.25	0.09
28				4.83	2.28	0.68	0.29	0.10
30				5.49	2.59	0.77	0.32	0.11
35				7.31	3.45	1.02	0.43	0.15
40				9.36	4.42	1.31	0.55	0.19
45				11.64	5.50	1.63	0.69	0.24
50				14.14	6.68	1.98	0.83	0.29
55					7.97	2.36	0.35	0.35
60					9.36	2.78	1.17	0.41
65					10.86	3.22	1.36	0.47
70					12.46	3.69	1.56	0.54
75					14.16	4.20	1.77	0.61
80						4.73	1.99	0.69
85						5.29	2.23	0.77
90						5.88	2.48	0.86
95						6.50	2.74	0.95
100						7.15	3.01	1.05
150						15.15	6.38	2.22
200							10.87	3.78
[illegible]								8.01

NOTE: Based on **C** = 140

TABLE 13.7 FRICTION LOSS - PVC SCHEDULE 40 PLASTIC PIPE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size							
	1/2"	3/4"	1"	1¼"	1½"	2"	2½"	3"
1	0.32	0.11	0.03	0.01				
2	1.14	0.39	0.12	0.03	0.02			
3	2.42	0.84	0.26	0.07	0.03	0.01		
4	4.13	1.42	0.44	0.12	0.05	0.02		
5	6.24	2.15	0.66	0.18	0.08	0.02	0.01	
6	8.75	3.02	0.93	0.25	0.12	0.03	0.01	
7	11.64	4.01	1.24	0.33	0.15	0.05	0.02	
8	14.90	5.14	1.59	0.42	0.20	0.06	0.02	
9	18.54	6.39	1.97	0.52	0.25	0.07	0.03	
10	22.53	7.77	2.40	0.63	0.30	0.09	0.04	0.01
11		9.27	2.86	0.75	0.36	0.11	0.04	0.02
12		10.89	3.36	0.89	0.42	0.12	0.05	0.02
14		14.48	4.47	1.18	0.56	0.17	0.07	0.02
16		18.55	5.73	1.51	0.71	0.21	0.09	0.03
18			7.13	1.88	0.89	0.26	0.11	0.04
20			8.66	2.28	1.08	0.32	0.13	0.05
22			10.33	2.72	1.29	0.38	0.16	0.06
24			12.14	3.20	1.51	0.45	0.19	0.07
26			14.08	3.17	1.75	0.52	0.22	0.08
28			16.15	4.25	2.01	0.60	0.25	0.09
30				4.83	2.28	0.68	0.29	0.10
35				6.43	3.04	0.90	0.38	0.13
40				8.23	3.89	1.15	0.49	0.17
45				10.24	4.84	1.43	0.60	0.21
50				12.45	5.88	1.74	0.73	0.26
55				14.85	7.01	2.08	0.88	0.30
60					8.24	2.44	1.03	0.36
65					9.56	2.83	1.19	0.41
70					10.96	3.25	1.37	0.48
75					12.46	3.69	1.56	0.54
80						4.16	1.75	0.61
85						4.66	1.96	0.68
90						5.18	2.18	0.76
95						5.72	2.41	0.84
100						6.29	2.65	0.92
150						13.33	5.62	1.95
200							9.57	3.33
250								5.03
300								7.05
350								9.38

NOTE: Based on C = 150

TABLE 13.8 FRICTION LOSS - PVC CLASS 160 PSI PLASTIC PIPE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size						
	1"	1½"	1½"	2"	2½"	3"	4"
1	0.02	0.01					
2	0.06	0.02	0.01				
3	0.14	0.04	0.02				
4	0.23	0.07	0.04	0.01			
5	0.35	0.11	0.05	0.02			
6	0.49	0.15	0.08	0.03	0.01		
7	0.66	0.20	0.10	0.03	0.01		
8	0.84	0.25	0.13	0.04	0.02		
9	1.05	0.31	0.16	0.05	0.02		
10	1.27	0.38	0.20	0.07	0.03	0.01	
11	1.52	0.45	0.23	0.08	0.03	0.01	
12	1.78	0.53	0.28	0.09	0.04	0.01	
14	2.37	0.71	0.37	0.12	0.05	0.02	
16	3.04	0.91	0.47	0.16	0.06	0.02	
18	3.78	1.13	0.58	0.20	0.08	0.03	
20	4.59	1.37	0.71	0.24	0.09	0.04	0.01
22	5.48	1.64	0.85	0.29	0.11	0.04	0.01
24	6.44	1.92	1.00	0.34	0.13	0.05	0.02
26	7.47	2.23	1.15	0.39	0.15	0.06	0.02
28	8.57	2.56	1.32	0.45	0.18	0.07	0.02
30	9.74	2.91	1.50	0.51	0.20	0.08	0.02
35		3.87	2.00	0.68	0.27	0.10	0.03
40		4.95	2.56	0.86	0.34	0.13	0.04
45		6.16	3.19	1.08	0.42	0.16	0.05
50		7.49	3.88	1.31	0.52	0.20	0.06
55		8.93	4.62	1.56	0.62	0.24	0.07
60		10.49	5.43	1.83	0.72	0.28	0.08
65			6.30	2.12	0.84	0.32	0.09
70			7.23	2.44	0.96	0.37	0.11
75			8.21	2.77	1.09	0.42	0.12
80			9.25	3.12	1.23	0.47	0.14
85			10.35	3.49	1.38	0.53	0.16
90				3.88	1.53	0.59	0.17
95				4.29	1.69	0.65	0.19
100				4.72	1.86	0.72	0.21
150				10.00	3.94	1.52	0.45
200					6.72	2.59	0.76
250					10.16	3.91	1.15
300						5.49	1.61
350						7.30	2.15
400						9.35	2.75
450							3.42
500							4.15
550							4.96
600							5.82
650							6.75
700							7.75
750							8.80

NOTE: Based on C=150

(Continued)

TABLE 13.8 (Cont'd) FRICTION LOSS - PVC CLASS 160 PSI PLASTIC PIPE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size				
	5"	6"	8"	10"	12"
40	0.01				
45	0.02				
50	0.02				
55	0.02				
60	0.03	0.01			
65	0.03	0.01			
70	0.04	0.02			
75	0.04	0.02			
80	0.05	0.02			
85	0.06	0.02			
90	0.06	0.03			
95	0.07	0.03			
100	0.08	0.03	0.01		
150	0.16	0.07	0.02		
200	0.27	0.12	0.03	0.01	
250	0.41	0.18	0.05	0.02	
300	0.58	0.25	0.07	0.02	0.01
350	0.77	0.33	0.09	0.03	0.01
400	0.98	0.42	0.12	0.04	0.02
450	1.22	0.52	0.14	0.05	0.02
500	1.48	0.63	0.18	0.06	0.03
550	1.77	0.76	0.21	0.07	0.03
600	2.08	0.89	0.25	0.08	0.04
650	2.41	1.03	0.29	0.10	0.04
700	2.77	1.18	0.33	0.11	0.05
750	3.14	1.34	0.37	0.13	0.06
800	3.54	1.51	0.42	0.14	0.06
850	3.96	1.69	0.47	0.16	0.07
900	4.41	1.88	0.52	0.18	0.08
950	4.87	2.08	0.58	0.20	0.09
1000	5.36	2.29	0.63	0.22	0.09
1100	6.39	2.73	0.76	0.26	0.11
1200		3.20	0.89	0.30	0.13
1300		3.72	1.03	0.35	0.15
1400		4.26	1.18	0.40	0.18
1500		4.84	1.34	0.46	0.20
1600			1.51	0.52	0.23
1700			1.69	0.58	0.25
1800			1.88	0.64	0.28
1900			2.08	0.71	0.31
2000			2.29	0.78	0.34
2500			3.46	1.18	0.52
3000				1.66	0.72
3500				2.20	0.96
4000				2.82	1.23
4500					1.53
5000					1.86

NOTE: Based on C = 150

TABLE 13.9 FRICTION LOSS - PVC CLASS 200 PSI PLASTIC PIPE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size						
	1"	1¼"	1½"	2"	2½"	3"	4"
1	0.02	0.01					
2	0.07	0.02	0.01				
3	0.14	0.04	0.02				
4	0.24	0.08	0.04	0.01			
5	0.36	0.12	0.06	0.02			
6	0.51	0.16	0.08	0.03	0.01		
7	0.67	0.22	0.11	0.04	0.01		
8	0.86	0.28	0.14	0.05	0.02		
9	1.07	0.34	0.18	0.06	0.02		
10	1.30	0.42	0.22	0.07	0.03	0.01	
11	1.56	0.50	0.26	0.09	0.03	0.01	
12	1.83	0.59	0.30	0.10	0.04	0.02	
14	2.43	0.78	0.40	0.14	0.05	0.02	
16	3.11	1.00	0.52	0.17	0.07	0.03	
18	3.87	1.24	0.64	0.22	0.09	0.03	
20	4.71	1.51	0.78	0.26	0.10	0.04	0.01
22	5.62	1.80	0.93	0.32	0.12	0.05	0.01
24	6.60	2.12	1.09	0.37	0.15	0.06	0.02
26	7.65	2.46	1.27	0.43	0.17	0.07	0.02
28	8.78	2.82	1.46	0.49	0.19	0.07	0.02
30	9.98	3.20	1.66	0.56	0.22	0.09	0.02
35		4.26	2.20	0.75	0.29	0.11	0.03
40		5.45	2.82	0.95	0.38	0.14	0.04
45		6.78	3.51	1.19	0.47	0.18	0.05
50		8.24	4.26	1.44	0.57	0.22	0.06
55		9.83	5.09	1.72	0.68	0.26	0.08
60		11.55	5.97	2.02	0.80	0.31	0.09
65			6.93	2.35	0.93	0.36	0.10
70			7.95	2.69	1.06	0.41	0.12
75			9.03	3.06	1.21	0.46	0.14
80			10.18	3.44	1.36	0.52	0.15
85				3.85	1.52	0.59	0.17
90				4.28	1.69	0.65	0.19
95				4.74	1.87	0.72	0.21
100				5.21	2.06	0.79	0.23
150				11.04	4.36	1.68	0.49
200					7.43	2.85	0.84
250						4.31	1.27
300						3.05	1.78
350						8.05	2.36
400							3.03
450							3.77
500							4.58
550							5.46
600							6.42

NOTE: Based on C=150

TABLE 13.9 (Cont'd) FRICTION LOSS PVC CLASS 200 PSI PLASTIC PIPE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size				
	5"	6"	8"	10"	12"
30	0.01				
35	0.01				
40	0.02				
45	0.02				
50	0.02				
55	0.03				
60	0.03	0.01			
65	0.04	0.02			
70	0.04	0.02			
75	0.05	0.02			
80	0.05	0.02			
85	0.06	0.03			
90	0.07	0.03			
95	0.08	0.03			
100	0.08	0.04	0.01		
150	0.18	0.08	0.02		
200	0.30	0.13	0.04	0.01	
250	0.45	0.19	0.05	0.02	
300	0.63	0.27	0.07	0.03	0.01
350	0.84	0.36	0.10	0.03	0.01
400	1.08	0.46	0.13	0.04	0.02
450	1.34	0.57	0.16	0.05	0.02
500	1.63	0.70	0.19	0.07	0.03
550	1.95	0.83	0.23	0.08	0.03
600	2.29	0.98	0.27	0.09	0.04
650	2.65	1.14	0.31	0.11	0.05
700	3.04	1.30	0.36	0.12	0.05
750	3.46	1.48	0.41	0.14	0.06
800	3.90	1.67	0.46	0.16	0.07
850	4.36	1.87	0.52	0.18	0.08
900	4.85	2.07	0.57	0.20	0.09
950	5.36	2.29	0.63	0.22	0.09
1000	5.89	2.52	0.70	0.24	0.10
1100	7.03	3.01	0.83	0.28	0.12
1200		3.53	0.98	0.33	0.15
1300		4.10	1.13	0.39	0.17
1400		4.70	1.30	0.45	0.19
1500		5.34	1.48	0.51	0.22
1600		6.02	1.66	0.57	0.25
1700			1.86	0.64	0.28
1800			2.07	0.71	0.31
1900			2.29	0.78	0.34
2000			2.52	0.86	0.38
2500			3.80	1.30	0.57
3000				1.83	0.80
3500				2.43	1.06
4000				3.11	1.36
4500				3.87	1.69
5000					2.05

NOTE: Based on C = 150

TABLE 13.10 FRICTION LOSS - PVC CLASS 315 PSI PLASTIC PIPE

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size							
	1/2"	3/4"	1"	1¼"	1½"	2"	2½"	3"
1	0.22	0.07	0.02	0.01				
2	0.78	0.27	0.09	0.03	0.01			
3	1.65	0.56	0.19	0.06	0.03	0.01		
4	2.82	0.96	0.32	0.10	0.05	0.02		
5	4.26	1.45	0.48	0.16	0.08	0.03	0.01	
6	5.97	2.03	0.67	0.22	0.11	0.04	0.02	
7	7.95	2.70	0.90	0.29	0.15	0.05	0.02	
8	10.18	3.45	1.15	0.37	0.19	0.06	0.03	
9	12.66	4.30	1.43	0.46	0.24	0.08	0.03	
10	15.38	5.22	1.74	0.56	0.29	0.10	0.04	0.01
11	18.35	6.23	2.07	0.67	0.35	0.12	0.05	0.02
12	21.56	7.32	2.43	0.79	0.41	0.14	0.05	0.02
14		9.74	3.24	1.05	0.54	0.18	0.07	0.03
16		12.47	4.15	1.34	0.70	0.23	0.09	0.04
18		15.51	5.16	1.67	0.87	0.29	0.12	0.04
20		18.86	6.27	2.03	1.05	0.35	0.14	0.05
22			7.48	2.42	1.25	0.42	0.17	0.06
24			8.79	2.84	1.47	0.50	0.20	0.08
26			10.19	3.29	1.71	0.58	0.23	0.09
28			11.69	3.78	1.96	0.66	0.26	0.10
30			13.29	4.29	2.23	0.75	0.30	0.11
35			17.68	5.71	2.96	1.00	0.39	0.15
40				7.31	3.80	1.28	0.51	0.19
45				9.10	4.72	1.59	0.63	0.24
50				11.06	5.74	1.94	0.76	0.29
55				13.19	6.85	2.31	0.91	0.35
60				15.50	8.04	2.71	1.07	0.41
65					9.33	3.15	1.24	0.48
70					10.70	3.61	1.42	0.55
75					12.16	4.10	1.62	0.62
80					13.71	4.62	1.82	0.70
85						5.17	2.04	0.78
90						5.75	2.27	0.87
95						6.35	2.51	0.96
100						6.99	2.76	1.06
150						14.81	5.84	2.24
200							9.95	3.82
250								5.77
300								8.09

NOTE: Based on C = 150

TABLE 13.11 FRICTION LOSS - ASBESTOS CEMENT, CLASS 150

Pressure Loss from Friction in psi per 100' of Pipe

Flow (gpm)	Nominal Size								
	3"	4"	5"	6"	8"	10"	12"	14"	16"
75	0.67	0.17							
100	1.14	0.28	0.10	0.04					
125	1.73	0.43	0.14	0.07					
150	2.42	0.60	0.20	0.09					
175	3.23	0.79	0.27	0.12					
200	4.14	1.02	0.34	0.16					
225	5.16	1.27	0.43	0.21					
250	6.24	1.55	0.52	0.24					
275	7.46	1.84	0.62	0.30					
300	8.76	2.15	0.73	0.34					
325	10.19	2.51	0.85	0.40	0.09				
350	11.66	2.87	0.97	0.45	0.11				
375	13.27	3.12	1.10	0.51	0.12				
400		3.68	1.25	0.58	0.14				
425		4.11	1.40	0.64	0.15				
450		4.60	1.55	0.72	0.17				
475		5.07	1.70	0.80	0.19				
500		5.55	1.87	0.87	0.21	0.07			
525		6.07	2.05	0.95	0.23	0.08			
550		6.63	2.23	1.05	0.25	0.08			
575		7.20	2.42	1.13	0.27	0.09			
600		7.80	2.62	1.22	0.29	0.10			
650		9.02	3.06	1.42	0.34	0.11			
700			3.49	1.62	0.39	0.13	0.06		
750			3.98	1.85	0.44	0.15	0.07		
800			4.47	2.09	0.50	0.16	0.07		
850			5.03	2.33	0.56	0.18	0.08		
900			5.54	2.61	0.62	0.20	0.09		
950			6.16	2.87	0.68	0.23	0.10	0.05	
1000			6.76	3.16	0.75	0.25	0.11	0.06	
1250				4.77	1.14	0.39	0.16	0.08	0.04
1500				6.68	1.60	0.53	0.23	0.11	0.06
1750					2.12	0.78	0.30	0.15	0.08
2000					2.71	0.90	0.40	0.20	0.10
2250					3.37	1.12	0.48	0.23	0.12
2500					4.11	1.36	0.60	0.26	0.15
2750						1.62	0.70	0.34	0.18
3000						1.90	0.82	0.40	0.21
3250						2.22	0.95	0.46	0.24
3500						2.53	1.10	0.53	0.28
4000						3.26	1.40	0.68	0.36
4500							1.74	0.84	0.44
5000							2.12	1.02	0.54
5500							2.53	1.22	0.65
6000								1.43	0.75
6500								1.66	0.87
7000								1.90	1.00
7500									1.15
8000									1.30
9000									1.60
10,000									1.95

NOTE: Based on C = 140

TABLE 13.12 APPROXIMATE COMPARATIVE FLOW CAPACITIES OF PIPE

Nominal Pipe Size (in)	1/2	3/4	1	1¼	1½	2	2½	3	4	6	8
1/2		2.5	4.8	8.2	13	25	43	68	137	297	590
3/4			2	3.3	5.1	10	17	27	55	147	292
1				1.7	2.6	5.2	9	14	28	80	160
1¼					1.5	3.1	5.3	8	17	40	80
1½						2.0	3.4	5.4	11	28	55
2							1.7	2.7	5.5	15	29
2½								1.6	3.2	9.5	19
3									2	5.5	11
4										2.8	5.5
6											2

Above figures show approximate number of smaller pipes required to carry the same flow as that in a single larger pipe with an equivalent pressure loss. These ratios vary somewhat with different types of piping materials and dimensions, and are intended only as a rough guide.

TABLE 13.13 APPROXIMATE PRESSURE LOSS IN PIPE FITTINGS

Expressed as Equivalent Footage of Pipe

Steel Fitting Type	Nominal Size (in)										
	1/2	3/4	1	1¼	1½	2	2½	3	4	6	8
Coupling	.6	.8	1.0	1.2	1.5	2.0	2.5	3.0	4.0	6.0	8.0
Run of St. Tee	1	1	1.5	2	2	2.5	3	4	5	7	10
Tee, Side Outlet	3	4.5	5	7	9	11	13	15	20	31	42
Tee, Run Reduced ½"	1.5	2.5	3	4	5	6	7	8	12	16	20
Elbow 90°	1.5	2.5	3	4	5	6	7	8	12	16	20
Elbow 45°	.75	1	1.3	1.7	2	2.5	3	3.5	5	7.5	10
Corporation Stop	9	9	9	9	9	9					
Curb Stop	6	6	7	7	8	8					

Plastic IPS or Copper Fitting Type	Nominal Size (in)										
	1/2	3/4	1	1¼	1½	2	2½	3	4	6	8
Coupling	1.5	2.5	3	3	4	6	7	8	11	18	24
Run of St. Tee	2.5	3	4	5	6	8	9	11	15	21	28
Tee, Side Outlet	7	9	12	15	18	24	30	36	45	70	90
Tee, Run Reduced ½"	3.5	4.5	6	8	9	11	14	17	24	34	45
Elbow 90°	3.5	4.5	6	8	9	11	14	17	24	34	45
Elbow 45°	1.5	2	3	3.5	4	5	7	8	10	16	20

TABLE 13.14 THEORETICAL FLOWS THROUGH NOZZLE ORIFICES AT 100% EFFICIENCY

Pressure (psi)	Nozzle Diameter (in.)												
	1/16	5/64	3/32	7/64	1/8	9/64	5/32	11/64	3/16	13/64	7/32	1/4	9/32
20	0.52	0.81	1.17										
25	0.58	0.90	1.31	1.78									
30	0.64	1.00	1.44	1.96	2.56								
35		1.08	1.55	2.11	2.77	3.50	4.31						
40			1.68	2.25	2.96	3.74	4.61						
45				2.40	3.13	3.99	4.91	5.91	7.03				
50				2.52	3.30	4.18	5.15	6.19	7.41	8.71			
55					3.46	4.37	5.39	6.48	7.77	9.12			
60						4.50	5.65	6.80	8.12	9.56	11.05	10.5	18.3
65								7.06	8.45	9.92	11.45	15.1	19.0
70								7.34	8.78	10.32	11.95	15.7	19.8
75										10.66	12.32	16.2	20.4
80										11.02	12.74	16.7	21.1
85												17.3	21.7
90												17.7	22.3

PART XIV – PUMP AND POWER SELECTION

14.1 Pumps

The pump selected for a specific application is based on two important factors: 1) the quantity and quality of water required (flow rate)
2) the TOTAL DYNAMIC HEAD required.

The flow rate of an irrigation system is determined by the maximum number of sprinklers that may be operating at the same time.

The total dynamic head required by an irrigation system consists of:

- static suction head (distance from water level at pumping rate to center of impeller).
- static discharge head (elevation from center of impeller to highest sprinklers in the system)
- friction head (total friction of all suction and discharge fittings and pipe)
- pressure head (pressure at sprinkler head)

14.1.1 Pump Horsepower Requirements

The brake horsepower required by an irrigation pump can be calculated by using the following formula:

$$H.P. = \frac{\text{Total flow (gpm)} \times \text{Total Dynamic Head (ft.)}}{3960 \times \text{Pump Efficiency (\%)}}$$

Example

A pump required to deliver 1000 gpm at 250 ft. of head and has an efficiency of 70% would require:

$$H.P. = \frac{1000 \times 250}{3960 \times 0.70} = 90 \text{ horsepower}$$

14.2 Centrifugal Pump

A horizontal centrifugal pump is most commonly used for irrigation applications having static suction head conditions of less than 20 ft. The pump selected should provide the operating requirements of the irrigation system at or close to its best efficiency point (B.E.P.).

The B.E.P.'s of centrifugal pumps vary from 45% to 80% but consideration should be given to selecting pumps that have efficiencies of 65% or better. A centrifugal pump should not be operated at less than 80% of its B.E.P. (i.e. If a pump has a B.E.P. of 80%, it should not be allowed to operate at an efficiency less than 64%).

Pump capacity and efficiency are reduced by excessively high suction lifts. For efficient pump operation the calculated Total Dynamic Suction Lift (TDSL) must be less than the allowable TDSL shown on the pump performance curves. The formula to calculate TDSL is:

$TDSL = He + Hl + Hv$

He = vertical distance from the water level to the centre line of the impeller eye (ft.)

Hl = friction loss in the suction system (ft.)

Hv = velocity head = $\frac{V^2}{2g}$ V = velocity of water in the suction line (ft./sec.)

g = acceleration due to gravity (32.2 ft/sec^2)

The calculated TDSL must be checked with the TDSL capability of the pump. The pump's TDSL ability is obtained from the pump performance curves. The TDSL values shown on the pump performance curves are for a pump operating at sea level at a water temperature of $70^{o}F$. Table 14.1 must be used to derate the TDSL ability of the pump for an increase in water temperature or altitude.

Table 14.1 Total Dynamic Suction Lift (TDSL) Correction For Altitude and Water Temperature

ALTITUDE (ft)	WATER TEMPERATURE (^{o}F) 40-70	100	120	130	140	150	160	170
Sea Level	0	1.3	3.0	4.4	6.0	8.0	10.5	13.5
2000	2.4	3.7	5.4	6.8	8.4	10.4	12.9	15.9
4000	4.7	6.0	7.7	9.1	10.7	12.7	15.2	18.2
6000	6.8	8.1	9.8	11.2	12.8	14.8	17.3	20.3
8000	8.8	10.1	11.8	13.2	14.8	16.8	19.3	22.3
10000	10.5	11.8	13.5	14.9	16.5	18.5	21.0	24.0

Once the TDSL has been calculated the Net Positive Suction Head Available (NPSHA) can be determined.

NPSHA - is the amount of energy (absolute pressure) that is available at the inlet to the pump.

NPSHA = 33 ft. - (correction factor from Table 14.1) - TDSL calculated for the suction system.

Cavitation will occur in a centrifugal pumping system if the Net Positive Suction Head Available (NPSHA) does not exceed the Net Positive Suction Head Required (NPSHR) by the pump.

NPSHR - is the amount of energy required to move water into the eye of the impeller without the formation of water vapour bubbles. (It is the minimum absolute pressure required above vapour pressure). The NPSHR will vary with different pump models and manufacturers. It is determined by the pump manufacturer by flow testing the different pump models.

The NPSHR of a pump does not change with water temperature or elevation. It is a characteristic of that pump model and impeller only. NPSHR is obtained from the pump performance curves.

NPSHR = 33 ft. - TDSL ability of the pump (at sea level)

When static suction head conditions exceed the capabilities of a centrifugal pump, (greater than 20 ft.) a vertical lineshaft turbine or submersible pump should be used.

14.2.1 Example of a Centrifugal Pump Selection

A pump is to deliver 350 gpm at 160 ft. of head, operating at an elevation of 4000 ft. with a water temperature of 60^{o}F. The total dynamic suction lift (TDSL) of the suction system has been calculated to be 15 ft. Which pump from Table 14.2 should be selected?

From Table 14.2A

The following information can be taken from the tables for pump A operating at 350 gpm at 170 ft. of head:

Impeller size	=	7 11/16"
Efficiency	=	68%
NPSHR	=	15.5 ft.
TDSL ability	=	17.5 ft. (at sea level)

The correction factor for the pump operating at 4000 ft. elevation is 4.7 ft. (from Table 14.1).

NPSHA = 33 ft. - 4.7 ft. - 15 ft. (TDSL calculated)
= 13.3 ft.

TDSL ability of the pump = 17.5 ft. - 4.7 ft. = 12.8 ft.
(at 4000 ft. elevation)

H.P. required = $\frac{350 \times 160}{3960 \times .68}$ = 21 H.P. (a 25 H.P. motor may be required)

Pump A would not be a good choice as the NPSHR (15.5 ft.) exceeds the NPSHA (13.3 ft.). Also, the TDSL ability of the pump is 12.8 whereas the existing suction conditions are 15 ft.

From Table 14.2B

The following information can be taken from the tables for pump B operating at 350 gpm at 160 ft. of head:

Impeller Size	=	6½"
Efficiency	=	77%
NPSHR	=	11.5 ft.
TDSL ability	=	21.5 ft. (at sea level)

The correction factor for the pump operating at 4000 ft. elevation is 4.7 ft. (from Table 14.1).

TABLE 14.2 EXAMPLE OF PUMP CURVES

TABLE 14.2A

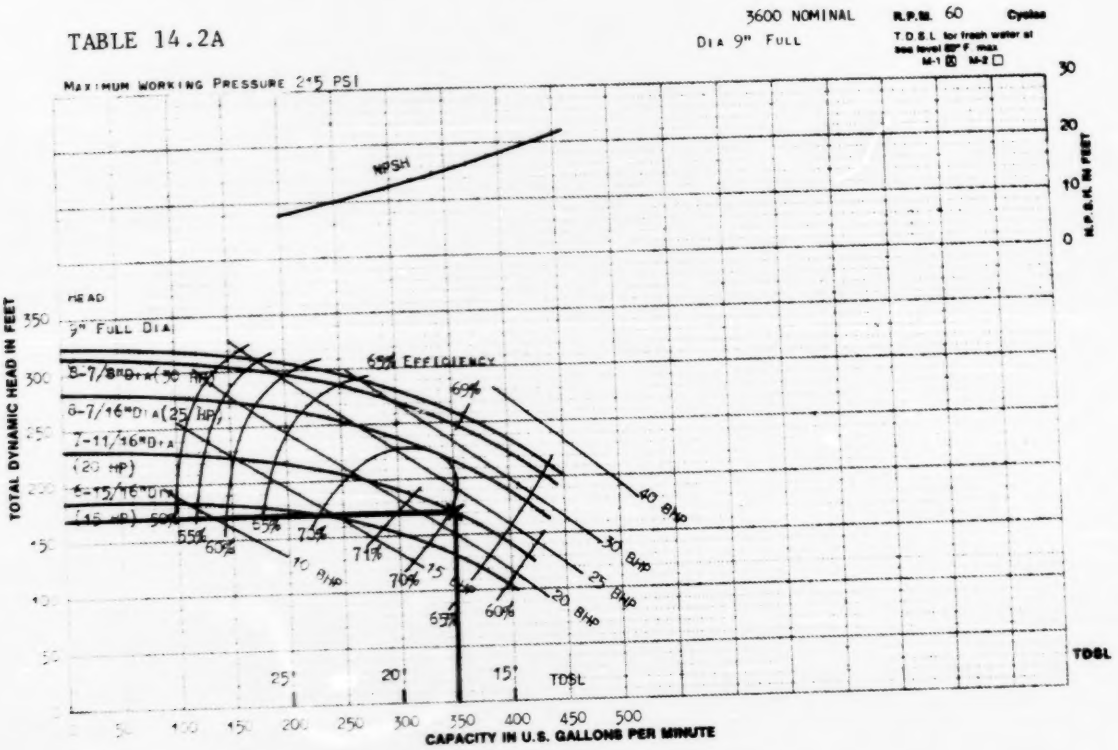
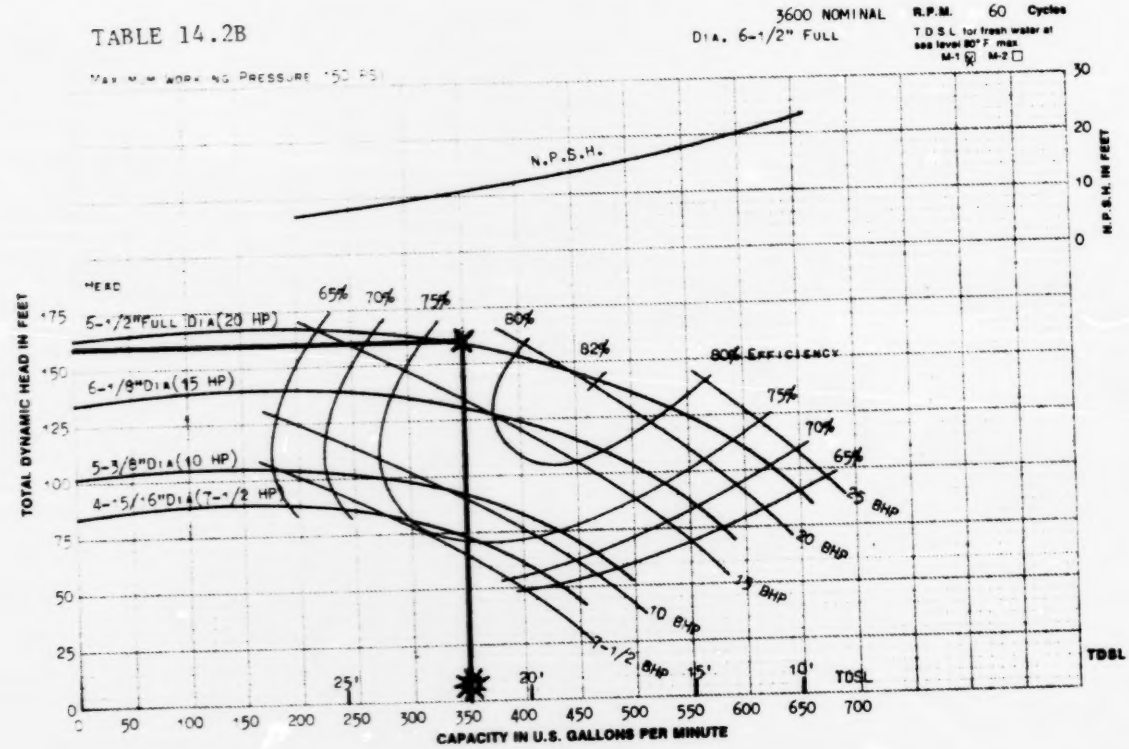


TABLE 14.2B



NPSHA = 33 ft. - 4.7 ft. - 15 ft. (TDSL calculated)

= 13.3 ft.

TDSL ability of the pump = 21.5 - 4.7 ft. = 16.8 ft.
(at 4000 ft. elevation)

H.P. required = $\frac{350 \times 160}{3960 \times .77}$ = 18.4 horsepower (20 H.P. motor may be required)

Pump B would be a logical choice as the NPSHA exceeds the NPSHR, thereby reducing the possibility of cavitation. Also, the pump is more efficient and would only require a 20 H.P. motor to operate it.

14.3 Turbine Pumps

Turbines fall into two general classifications, open impeller and closed impeller. Open impeller bowls can be adjusted to regulate the total head and capacity or to compensate for wear. Closed impeller pumps have less down thrust and are better suited to variable head conditions as they are less sensitive to shaft elongation.

For optimum life turbines should not exceed 1800 R.P.M. Submersible pumps usually operate at 3600 R.P.M. which in some cases allows a smaller well diameter than a turbine. Submersibles are faster to install and remove from a well for repair but motors can not be repaired at local rewind shops.

When considering a deep well pump both submersibles and turbines should be considered.

Wells should be at least one nominal size larger than the pump (i.e., a six inch pump should be set in an 8 inch well).

Provisions should be made for sounding the well without removing the pump.

TABLE 14.3 RECOMMENDED WELL DIAMETERS

Anticipated Well Yield (gpm)	Nominal Size of Pump Bowls (in)	Optimum Size of Well Casing (in)	Smallest Size of Well Casing (in)
Less than 100	4	6 ID	6 ID
75 to 175	5	8 ID	8 ID
150 to 400	6	10 ID	8 ID
350 to 650	8	12 ID	10 ID
600 to 900	10	14 OD	12 ID
850 to 1300	12	16 OD	14 OD
1200 to 1800	14	20 OD	16 OD
1600 to 3000	16	24 OD	20 OD

14.4 Power

Electric motors and internal combustion engines fueled by natural gas, propane, gasoline and diesel, are the most common sources of power units for pumping water.

Electric motors, when properly selected and protected, can be expected to supply trouble-free power for many years. Factors that influence the selection of an electric motor include such items as: maintenance, dependability, ease of operation, phase of power available, and distance of power source to pumping plant. Single phase power is limited to 10 H.P. motors unless PHASE CONVERTERS are used. The rated horsepower can usually be assumed to be the out-put horsepower, because of the high efficiency of motors. Contact local power suppliers regarding all power line limitations.

When selecting phase converters, consideration should be given to the various types. Rotary type converters maintain a good balance between phases under changing load conditions. Capacitor type converters are balanced at a set power requirement, if the load changes the voltage can vary between phases.

Internal combustion engines are less efficient than electric motors and the shaft output horsepower should be known in sizing the correct motor requirement. Manufacturers select the power unit and pump in a package pumping unit so that not only are speeds compatible but also maximum engine life and economical performance are achieved. Consideration must be give to altitude and ambient temperature when choosing internal combustion engines. Engine manufacturers have several ways of rating engine horsepower. Net continuous crankshaft h.p. output, (with all allowances for accessories considered) is the figure to use.

A decrease in output of 3% per 1000 feet of elevation above sea level, an additional 1% loss per 5^{o} Farenheit above 68^{o} Farenheit and a further 3% loss per 10% humidity increase above 65% should be allowed.

PART XV - GENERAL CONSIDERATIONS

1. Laterals should be placed across slopes.
2. Mainlines should be placed up and down hills.
3. Bury mainlines below frost levels or provide adequate draining facilities in all low spots.
4. Anchor mainlines at all major directional changes and support lines under take-off hydrants.
5. Snake pipeline installations to allow for expansion.
6. Pipe sizes should be balanced with economical pumping costs.
7. Do not bury uncoated aluminum. When installing coated aluminum lines include automatic drain plugs.
8. AIR RELIEF VALVES should be located at major summits.
9. Vacuum relief valves should be installed in downhill draining mainlines.
10. Non-slam check valves should be used to prevent backflow and retain pump prime.
11. By-pass valves are necessary to take care of high pressure situations, especially in turbine applications.
12. Back-flow prevention device must be installed when required by local by-laws. ALWAYS USE AN ANTI-SIPHONAGE DEVICE WHEN USING CHEMICAL OR FERTILIZER INJECTION EQUIPMENT.
13. Screens must be sized for openings and area to keep out material that would plug sprinklers and emitters and also to meet the specifications of the Ministry of Fisheries where fish may be involved.
14. Abrasive sediments should be kept out of the system.
15. Overload protection switch should be used in electrical motor applications.
16. Install loss of prime switch.
17. Install low water pressure cut-out switch.
18. Install low oil pressure cut-off in combustion engines.
19. Install high water temperature cut-off in combustion engines.
20. Obtain Water Rights licenses.
21. Install surge chambers when water hammer is anticipated.
22. Pump stations should be sheltered and well ventilated.
23. Flow control valves should be considered when lateral pressures have large variations.

APPENDIX I

PROCEDURE FOR SOIL SAMPLING FOR SYSTEM DESIGN

Procedure Outline

-Prepare a soil sampling map (2 copies, 1 copy for your own reference)

-Locate boundaries between major soils and mark on map

-Sample each major soil in two places

-Take samples at five different depths

-Label samples

-Mark special features on map

-Submit map and samples to District Agricultural office

SOIL TEXTURE

It is necessary to be able to recognize different soil textures in the field. To do this properly a certain amount of practice is required. A guide which briefly outlines a method of determining texture in the field by the "hand-feel" method may be found on the following pages.

BASE MAP

Prepare a soil sampling map similar to the example shown on the following pages. Mark the type of crops to be grown on the various fields.

SEPARATING DISTINCTLY DIFFERENT SOILS

Before sampling determine whether the soil is basically the same all over or if two or more distinctly different soils are present. For example, if a 60-acre farm has 20 acres of peat and 40 acres of clay, then the location of the boundary between these two soils should be known and marked on the map. The best way to determine whether different soils are present and where their boundary is located is as follows:

Method of Separation

- In most cases the major soil divisions on a farm are known; if not, systematically dig a series of pits in grid pattern at 300 or 400 foot intervals to a depth of about 30 inches.

-If a major change occurs, say from clay to peat between one pit and the next the point of change should be marked on the map.

-Continue in this manner until enough points are known to mark the boundary on the map with reasonable accuracy.

TAKING SOIL SAMPLES

Sample each major soil in two different places (that is, two holes per major soil type).

Where to Sample

Select a site where the soil is similar over a large area. In other words; choose a location well away from the boundary with another soil. Avoid the top of small ridges and the bottom of small depressions. Make sure the sample hole is representative to the texture area involved.

How to Sample

-Dig a pit 3 to 4 feet deep (make it large enough!)

-Force shovel about an inch into the side of pit, 6 inches below surface.

-With a knife scrape approximately ½ pound of soil from the side of the pit onto the shovel, ensuring a representative sample from the surface to the 6" depth.

-Deposit sample into a one pint plastic freezer bag and mark label as follows:

J.B. Jones
Pit A
Depth: 0 - 6"

-Tie label to outside of bag (OUT OF CONTACT WITH THE SOIL)

-Proceed sampling in this manner at the following depths:

0" - 6"
6" - 12"
12" - 24"
24" - 36"
36" - 48"

-If a sharp texture change occurs in between these levels, take a sample for the layer indicating the depths involved.

-Mark the location of each sampling site on the soil sampling, map and identify it with a letter (Pit A, B, C, D, etc.).

SPECIAL FEATURES

Mark areas with special features on the soil sampling map and indicate the nature such as:

-Stoniness (scattered, medium, very stony)

-Poor drainage - seepage areas

-Gravel ridges

-Depth to the water table (if present)

SOIL TEXTURING GUIDE

-Take a handful of soil

-Add small maounts of water while kneading soil until clods are broken down and soil becomes pasty.

-Determine texture by rubbing soil paste between finger and thumb and using the guide below.

Texture Guide

Gravel - Usually from peat to egg-sized stones

Sand - Feels "gritty" and will not form a ball when pressed together

Silt - Soapy or velvet like - will form a ball

Clay - Sticky - will form tight ball

Loam - Mixture of sand, silt and clay

Soils rarely consist of pure sand, silt, clay or gravel. Usually the soil is a mixture of these components and is described as

Sand)
Loamy Sand) - Light or coarse textured soil
Sandy Loam)

Loam)
Fine Sandy Loam) - Medium textured soil
Silt Loam)

Clay Loam)
Silty Clay Loam) - Heavy or fine textured soil
Silty Clay)
Clay)

SAMPLE BASE MAP

Name:

Address:

Legal Description:

Tag required for each sample.

*Usually five samples per sampling site.

GLOSSARY OF TERMS

Air Relief Valve - A device that releases air from a pipe line automatically without permitting loss of water. It may also admit air to the pipe automatically if the internal pressure becomes less than atmospheric.

Annual Irrigation Requirement - The water required annually for maximum demand crops.

Application Efficiency - The ratio of net depth of desired application to the gross depth of water delivered by the irrigation system.

Application Rate - The rate at which irrigation water is applied to the soil in inches per hour.

Availability Coefficient - The maximum fraction of available water storage capacity to be removed before irrigation is required.

Available Water Storage Capacity (AWSC) - The depth of soil water retained between field capacity and permanent wilting point.

Backflow Preventor - A device that prevents water from reversing its flow and thereby prevents contamination of the supply system.

Crop Coefficient Factor - Adjustment used for daily water requirement of plant in relation to canopy, root area, plant shape and spacing.

Center-Pivot - A trussed piping network supported by towers on wheels that travel in a circle or part circle around a pivot point.

Coefficient of Uniformity - The percentage of deviation from the average application of water from sprinklers.

Effective Rooting Depth - That depth in the soil above which the roots obtain 90% or more of their water between irrigations.

Emitter - A device used in trickle irrigation to dispense water at a given rate.

Emitter Line - In trickle irrigation, the line which distributes water to the individual emitters.

Evapotranspiration (ET) - Water transpired by plants and evaporated from the soil surface.

Flow Control Valve - A device for regulating the flow to a sprinkler or an irrigation system.

Hand-Move Sprinkler System - A system of piping which is moved manually after uncoupling the pipes.

Header - Sometimes call manifold, a line feeding laterals or emitter lines.

Instantaneous Application Rate - The average amount of water applied by a single sprinkler over a given area.

Irrigation Interval - The number of days between the start of an irrigation at any one setting and the start of the next irrigation at the same setting.

Lateral Line - In sprinkler irrigation, the pipe lines which supply water to individual sprinklers.

Maximum Soil Water Deficit - The maximum amount of water allowed to be removed from the soil before irrigation is required.

Overlap Application Rate - the amount of water applied to the soil by a series of sprinklers over an irrigation interval.

Phase Convertor - A device which enables a three-phase motor to operate on single-phase power.

Pressure Relief Valve - A device used to relieve excessive pressure and surges, spring loaded and usually set to open at a pressure slightly above the operating pressure.

Root Area - The lateral area occupied by the root system of a plant.

Set Time - The amount of time required to apply the designed depth of water in one location.

Solid Set System - A solid set system may be either permanent or portable and will cover a complete field with pipes and sprinklers in such a manner that only water pressure has to be applied, either in its entire area or in sections, by controlling the flow with valves.

Stationary Giant Gun - Large volume impact sprinkler.

Total Dynamic Head - The energy measured in feet imparted by the pump, measured in feet, equal to the sum of static lift, friction head, static discharge head and pressure head.

Travelling Gun Sprinkler - Large volume impact sprinkler that is being moved continually when operating.

Trickle Irrigation - Sometimes referred to as drip irrigation - The application of water to the plant in an amount sufficient to replenish the water used during the past day, plus a necessary excess to leach harmful salts from the root zone.

Vacuum Relief Valve - A device used on supply lines, or main lines that normally drain downhill to prevent a vacuum from developing in the line.

Water Allotment - The amount of water that an Irrigation District will provide for a particular parcel of land.

Wheel Move Sprinkler System - A system that usually employs a lateral pipeline as an axle. Wheels are mounted on the lateral, and the lateral is moved at right angles to its longitudinal axis by rotating the pipeline by engine power.

Zone - A portion of an irrigation distribution system that is operated at any one time.

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METRIC CONVERSION FACTORS

FLOW

1 gallon per minute (U.S.)	=	3.78 litres per minute
1 gallon per minute (Imp.)	=	4.55 litres per minute
1 cubic foot per sec. (cfs)	=	1700 litres per minute
1 cubic metre per hour	=	1000 litres per hour
	=	16.67 litres per minute
1,000,000 gal. per day (U.S.)	=	694.4 gallons per minute (U.S.)
	=	2625 litres per minute

VOLUME

1 gallon (U.S.)	=	3.78 litres
1 gallon (Imp.)	=	4.55 litres
1 cubic foot	=	7.48 gallons (U.S.)
	=	28.32 litres
1 acre-foot	=	43,560 cubic feet
	=	1233.6 cubic metres
1 cubic metre	=	1000 litres
	=	264.16 gallons (U.S.)
	=	219.97 gallons (Imp.)
	=	35.31 cubic feet

AREA

1 hectare	=	2.47 acres
	=	10,000 sq. metres
1 acre	=	43,560 sq. ft.

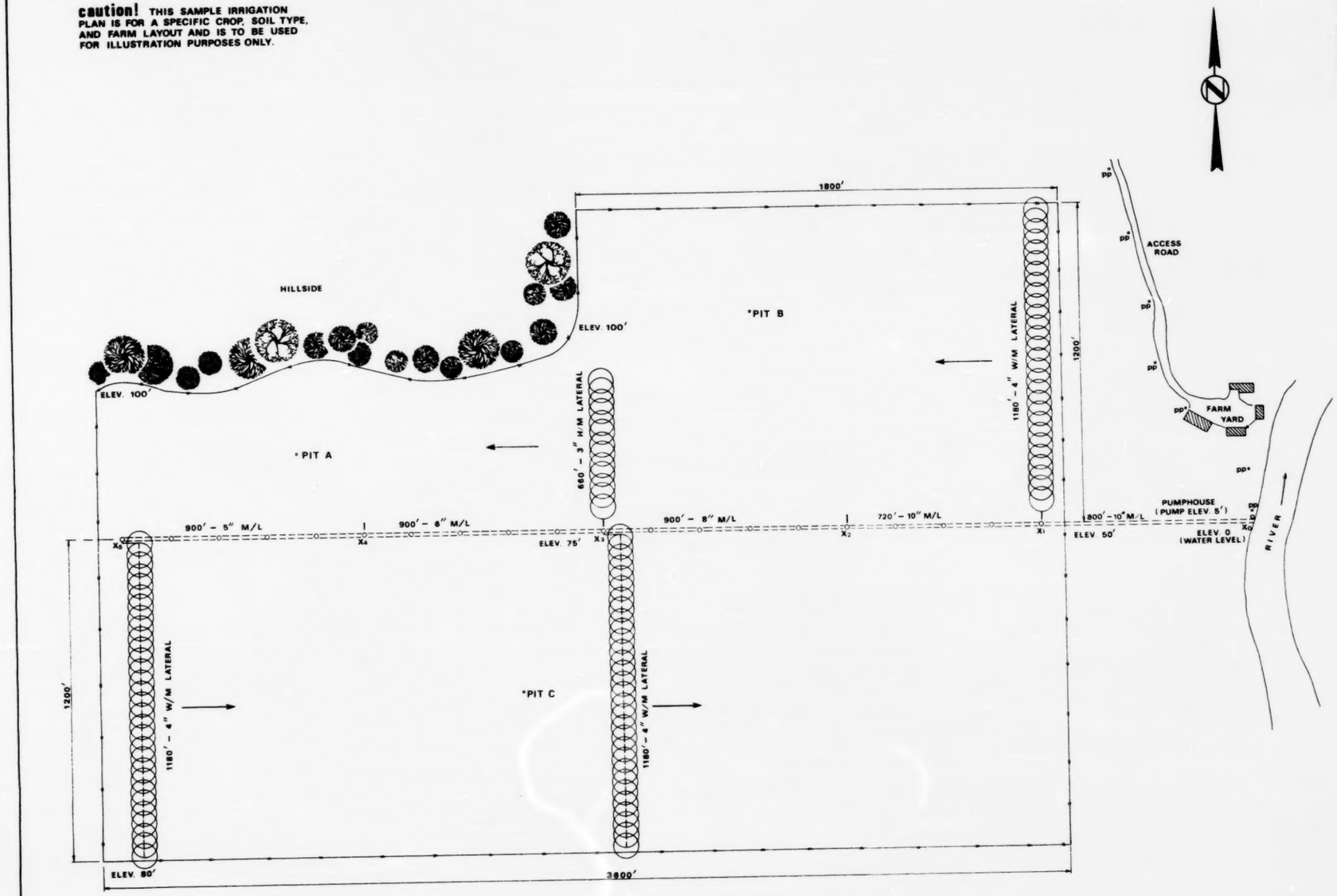
LINEAL

1 inch	=	2.54 cm
1 foot	=	30.48 cm
1 metre	=	3.28 ft.
1 mile	=	1.61 kilometre

PRESSURE

1 atmosphere	=	29.92 inches of Hg @ 32°F
	=	33.94 ft. of water @ 62°F
	=	14.7 pounds per sq. inch (psi)
1 pound per sq. inch (psi)	=	2.31 ft. of water
1 bar	=	0.98 atmospheres
	=	100 kilopascals
	=	14.5 pounds per sq. inch (psi)
1 pound per sq. inch (psi)	=	6.90 kilopascals

caution! THIS SAMPLE IRRIGATION PLAN IS FOR A SPECIFIC CROP, SOIL TYPE, AND FARM LAYOUT AND IS TO BE USED FOR ILLUSTRATION PURPOSES ONLY.



IRRIGATION DESIGN INFORMATION

Soils Report

Pit	Crop and Root Depth (in.)	Depth (in.)	Texture	AWSC (in./ft.)	AWSC (in.) Total	Max. A.R. (in./hr.)
A	48 in.	0-12	SANDY LOAM	1.5		
B &	in.	12-24	FINE SL	1.8		
C	ALFALFA	24-36	SANDY LOAM	1.5	8.0	0.45
		36-48	LOAMY SAND	1.2		

Design Parameters

Crop	ALFALFA
Root depth	4 ft.
Soil type	SANDY LOAM
Total available water storage capacity (AWSC)	8.0 in.
Usable amount of water (50 % AWSC)	3.0 in.
Maximum application rate (AR)	0.45 in./hr.
Evapotranspiration rate (ET)	0.30 in./day

Design Data

Interval	15 days
Set time	11½ hours
Gross applied per irrigation	4.17 in.
Net applied @ 72 % efficiency	3.0 in.
Application rate	0.26 in./hr.
Spacing	40 x 90
Nozzle	7/32 = 5/32
Pressure at the nozzle	48 psi
Gallons per minute per nozzle	80 gpm

Mainline Friction Loss Calculations

X_0 - X_1	800'	10"	AL	@ 983	gpm	8.0	x 0.26	= 2.08 psi
X_1 - X_2	720'	10"	AL	@ 983	gpm	7.2	x 0.26	= 1.87 psi
X_2 - X_3	900'	8"	AL	@ 893	gpm	9.0	x 0.42	= 3.78 psi
X_3 - X_4	900'	6"	AL	@ 623	gpm	9.0	x 0.96	= 8.64 psi
X_4 - X_5	900'	5"	AL	@ 270	gpm	9.0	x 0.89	= 8.21 psi
x - x		"		@	gpm		x	=
x - x		"		@	gpm		x	=
x - x		"		@	gpm		x	=

Total friction loss in mainline (M/L) . . . . 19.89 psi = 45.9 ft.

Total Head Required

Pressure required at start of lateral @ 57 psi	132 ft.
Total friction loss in mainline	46 ft.
Elevation	95 ft.
Suction lift	5 ft.
Miscellaneous losses	10 ft.
Total head required	288 ft.

Pump Specifications

Total head required	288 ft.
Total gpm required 1107 x 8.0	983 gpm
Minimum pump efficiency	65 %
Model (To be filled in by Dealer)	xxx-yyy

Horsepower Required

$$H.P. = \frac{288 \text{ ft.} \times 983 \text{ gpm}}{3960 \times 65\ \%} = 108 \text{ hp}$$

Legend

M/L	Mainline
W/M	Wheelmove
H/M	Handmove
oB	Soil test hole sites
oPP	Power pole location
Elev. 75'	Elevation
	Fenceline boundary
	M/L with hydrants @ 180 ft.
	Lateral
	Bush
	Road
	Ditch
	Buildings

SCALE : 1" = 200'
(This plan has been reduced.)

0 200 400 600 800 1000

DATE	REVISION

B.C Ministry of Agriculture and Food
AGRICULTURAL ENGINEERING BRANCH

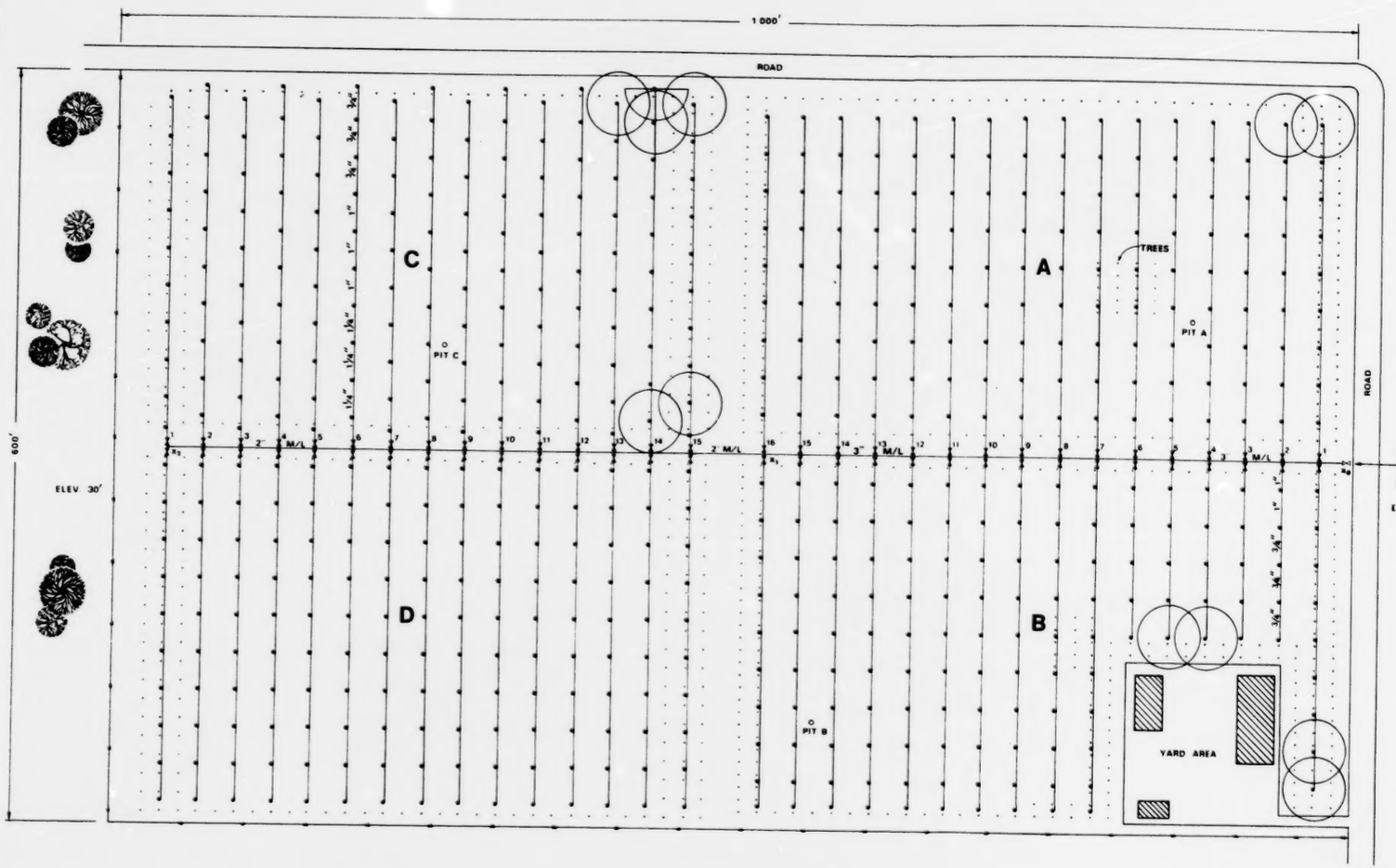
SAMPLE IRRIGATION PLAN
WHEEL MOVE SYSTEM

DESIGNED T. Van der Gulik	SCALE 1" = 200'
DRAWN L. Bosher	DATE July 1980
TRACED _	SHEET 1 OF 1
	PLAN NO. 580.002

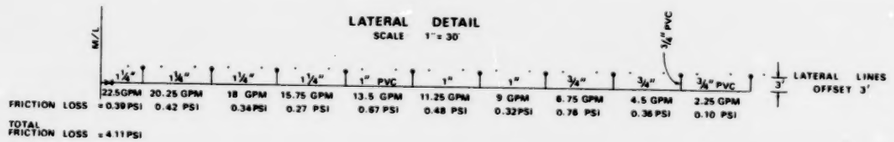
SCS 1780 0041

caution! THIS SAMPLE IRRIGATION PLAN IS FOR A SPECIFIC CROP, SOIL TYPE, AND FARM LAYOUT AND IS TO BE USED FOR ILLUSTRATION PURPOSES ONLY.

WATER ALLOTMENT 6.5 U.S. GPM/ACRE x 13.8 ACRES = 90 GPM



LATERAL DETAIL
SCALE 1" = 30'



Block A **Apples** 15' x 10' TREE SPACING
30' x 30' SQUARE SPRINKLER SPACING

B **Peaches** 15' x 10' TREE SPACING
30' x 30' SQUARE SPRINKLER SPACING

C **Cherries** 15' x 15' TREE SPACING
30' x 30' TRIANGULAR SPRINKLER SPACING

D **Pears** 15' x 15' TREE SPACING
30' x 30' SQUARE SPRINKLER SPACING

IRRIGATION DESIGN INFORMATION

Soils Report

Pit	Crop and Root Depth (in.)	Depth (in.)	Texture	AWSC (in./ft.)	AWSC (in. Total	Max. A.R. (in./hr.)
A	48 in.	0-12	SANDY LOAM	1.5		
B	in.	12-24	SANDY LOAM	1.5		
C	TREE-FRUITS	24-36	LOAMY SAND	1.2	5.2	0.45
		36-48	SAND	1.0		

Design Parameters

Crop	TREE-FRUITS
Root depth	4 ft.
Soil type	LOAMY-SAND
Total available water storage capacity (AWSC)	5.2 in.
Usable amount of water (40 % AWSC)	2.08 in.
Maximum application rate (AR)	0.45 in./hr.
Evapotranspiration rate (ET)	0.28 in./day

Design Data

Interval	8 days
Set time	12 hours
Gross applied per irrigation	2.89 in.
Net applied @ 72 % efficiency	2.08 in.
Application rate	0.24 in./hr.
Spacing	30 x 30
Nozzle	1/4"
Pressure at the nozzle	30 psi
Gallons per minute per nozzle	2.25 gpm

Mainline Friction Loss Calculations

x_0 - x_1	480'	3"	PVC	@ 90	gpm	4.8	x 0.59	= 2.83	psi
x_1 - x_2	480'	2"	PVC	@ 45	gpm	4.8	x 1.09	= 5.19	psi
x - x				@	gpm		x	=	
x - x				@	gpm		x	=	
x - x				@	gpm		x	=	
x - x				@	gpm		x	=	
x - x				@	gpm		x	=	
x - x				@	gpm		x	=	

Total friction loss in mainline (M/L) . . . . 8.01 psi = 18.5 ft.

Total Head Required

Pressure required at start of lateral @ 34.1 psi	78.8 ft.	
Total friction loss in mainline	18.5 ft.	
Elevation	30.0 ft.	
Suction lift	ft.	
Miscellaneous losses	8.0 ft.	
Total head required	133.3 ft.	= 58 psi

Pump Specifications

Total head required	ft.
Total gpm required	gpm
Minimum pump efficiency	%
Model (To be filled in by Dealer)	

Horsepower Required

$$H.P. = \frac{\text{ft.} \times \text{gpm}}{3960 \times \%} = \text{hp}$$

Legend

M/L	Mainline
W/M	Wheelmove
H/M	Handmove
oB	Soil test hole sites
oPP	Power pole location
Elev. 75'	Elevation
	Fenceline or boundary
	M/L with hydrants @ ____ ft.
	Lateral
	Bush
ROAD	Road
DITCH	Ditch
	Buildings
	Valve
•	Sprinkler

SCALE: 1" = 50'
(This plan has been reduced.)

0 50 100 150 200 ft.

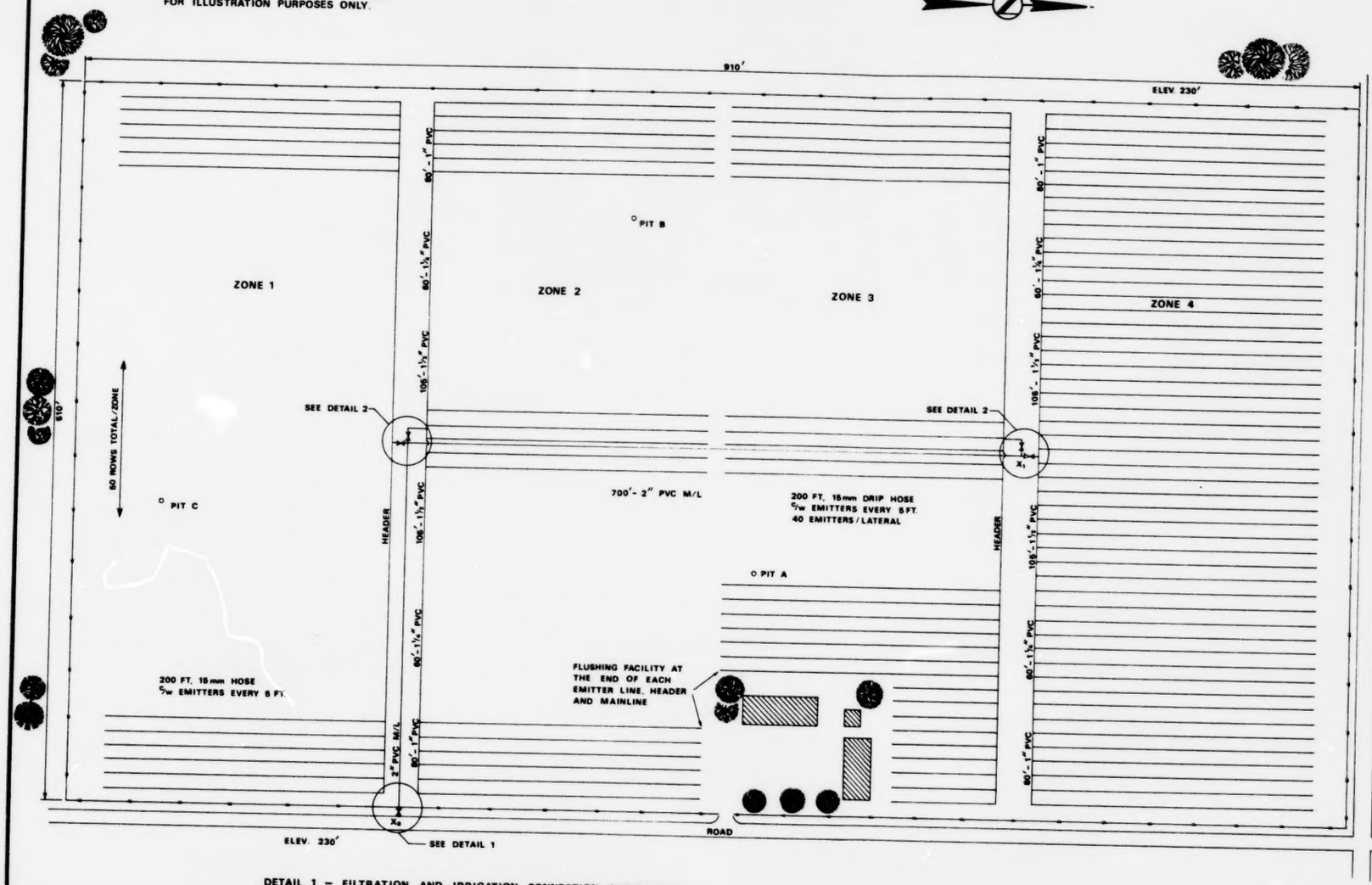
DATE	REVISION

B C Ministry of Agriculture and Food
AGRICULTURAL ENGINEERING BRANCH

SAMPLE IRRIGATION PLAN SOLID SET UNDERTREE

DESIGNED T. Van der Gulik	SCALE 1" = 50'
DRAWN L. Scobar	DATE MAY 1980
TRACED _	SHEET 1 OF 1
	PLAN NO 550.082

caution ! THIS SAMPLE IRRIGATION PLAN IS FOR A SPECIFIC CROP, SOIL TYPE AND FARM LAYOUT AND IS TO BE USED FOR ILLUSTRATION PURPOSES ONLY.



IRRIGATION DESIGN INFORMATION

Soils Report

Pit	Crop and Root Depth (in.)	Depth (in.)	Texture	Lateral Spread of Water
A	48 in.	0 - 18	LOAM	6.0 - 7.0 FT
B	____ in.	18 - 34	LOAM	
C	RASPBERRIES	34 - 36	SANDY LOAM	
		36 - 48	SANDY LOAM	

Design Parameters

Crop	RASPBERRIES
Root depth	4 ft.
Soil type	LOAM
Plant spacing	2½ FT x 10 FT
Row length	200 ft.
Plants per row	80
Rows per zone	60
District allotment	60 gpm
Evapotranspiration rate	0.25 in./day

Design Data

Emitter spacing	5 FT along rows
Emitter operating pressure	15 psi
Emitter discharge	1 gph
Gallons / plant / per day	2.9 gallons
Emitter operating time	5.6 hrs
Water required / zone	333 gpm

NOTE: — 1 Emitter / 2 Plants

Mainline Friction Loss Calculations

$x_0 - x_1$ 700' - 2" PVC @ 34 gpm - 0.87 psi x 7 = 4.88 psi
Elevation 0 ft
NOTE: — Emitter operating pressure 15 psi
Pressure available 50 psi - 4.88 psi = 45.31 psi

Pressure reducing valves are required at each zone

Zone Friction Loss Calculations

Maximum loss allowable within zone is ±10% of emitter operating pressure of 15psi = ±1.5psi

Header Friction Loss

8 laterals on 1" PVC — 80 ft. - 1"	0.25 psi	
Additional 8 laterals on 1¼" PVC — 80 ft. - 1¼"	0.36 psi	
Additional 11 laterals on 1½" PVC — 105 ft. - 1½"	0.46 psi	
35 laterals	Total	1.08 psi
Header fitting loss (30% of 1.08 psi)		0.81 psi

Lateral and Emitter Friction Loss

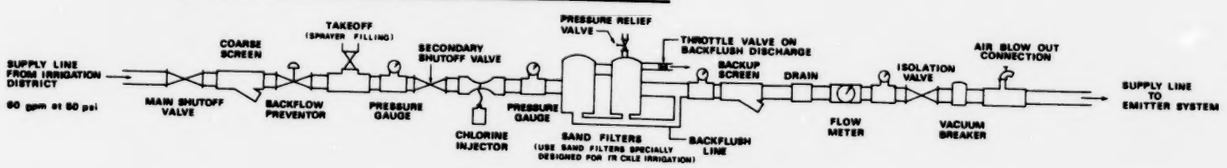
300' of 16mm hose with 5' emitter spacing 0.38 psi

Total friction loss in zone 1.51 psi

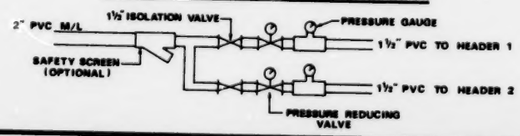
Legend

M/L	Mainline
oB	Soil Test Hole Sites
Elev. 75'	Elevation
	Fenceline or Boundary
	Bush
	Buildings
	Isolation Valves
	Pressure Reducing Valve
	Pressure Gauge

DETAIL 1 – FILTRATION AND IRRIGATION CONNECTION COMPONENTS



DETAIL 2 – MAINLINE – HEADER CONNECTION



SCALE: 1" = 40'
(This plan has been reduced)
0 20 40 60 80 100

DATE	REVISION

B.C. Ministry of Agriculture and Food
AGRICULTURAL ENGINEERING BRANCH

SAMPLE TRICKLE IRRIGATION PLAN ON RASPBERRIES

DESIGNED T. Van der Gulik	SCALE 1" = 40'
DRAWN L. Bashor	DATE JULY 1986
TRACED	SHEET 1 OF 1
	PLAN No. 585.005